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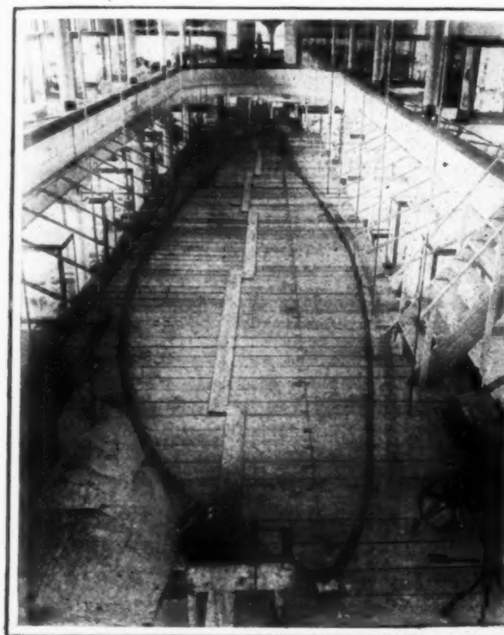


FIG. 1.—THE BACKBONE AND VENTRAL LINES.

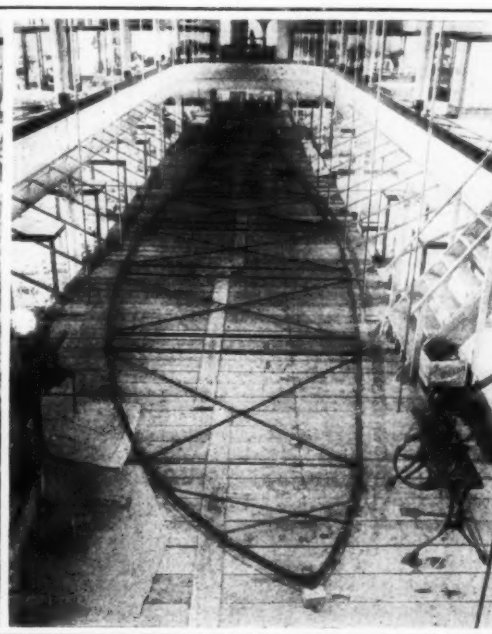


FIG. 2.—THE CROSS BRACING OF THE FRAMEWORK.

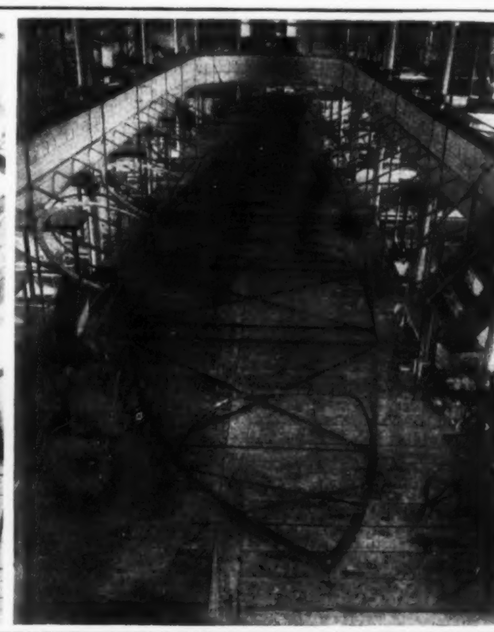


FIG. 3.—THE IRON RIBS PLACED ON ONE SIDE.

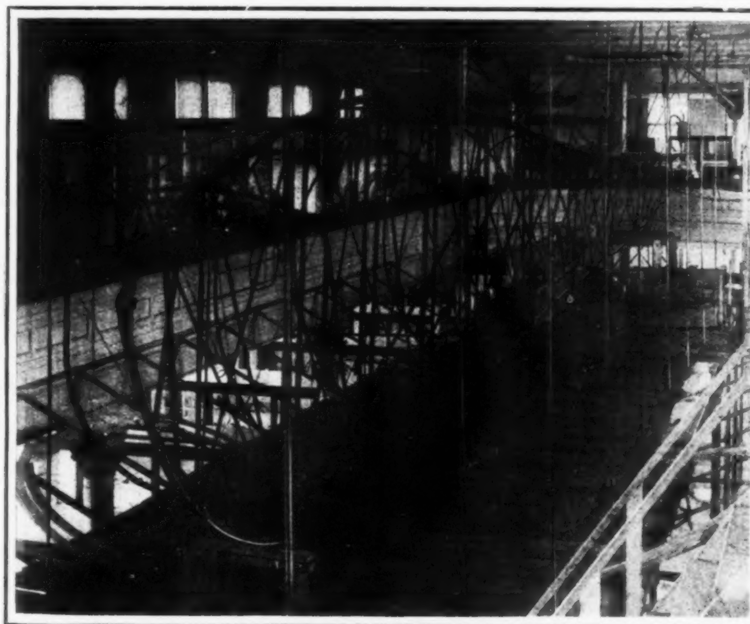


FIG. 4.—THE IRON FRAMEWORK OF THE WHALE READY FOR THE WOODEN RIBS.

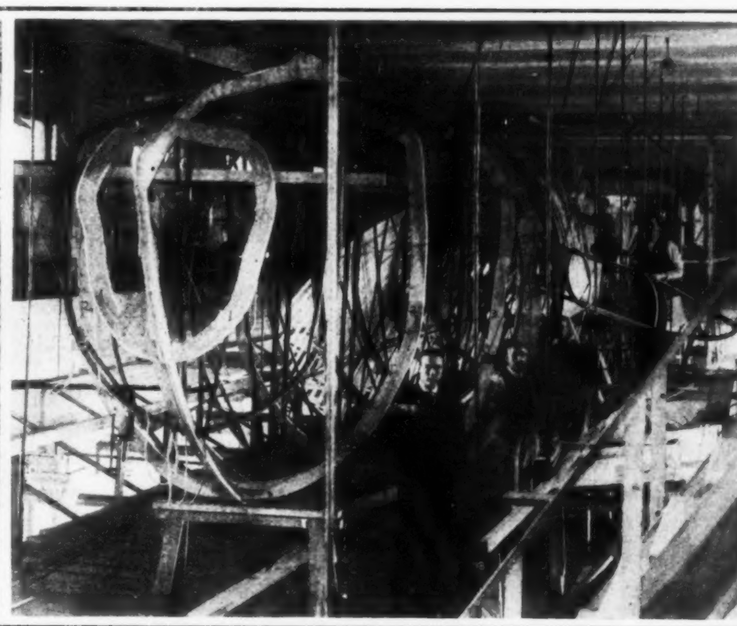


FIG. 5.—THE FINAL "SKELETON" WITH THE WOODEN FRAMEWORK ADDED.

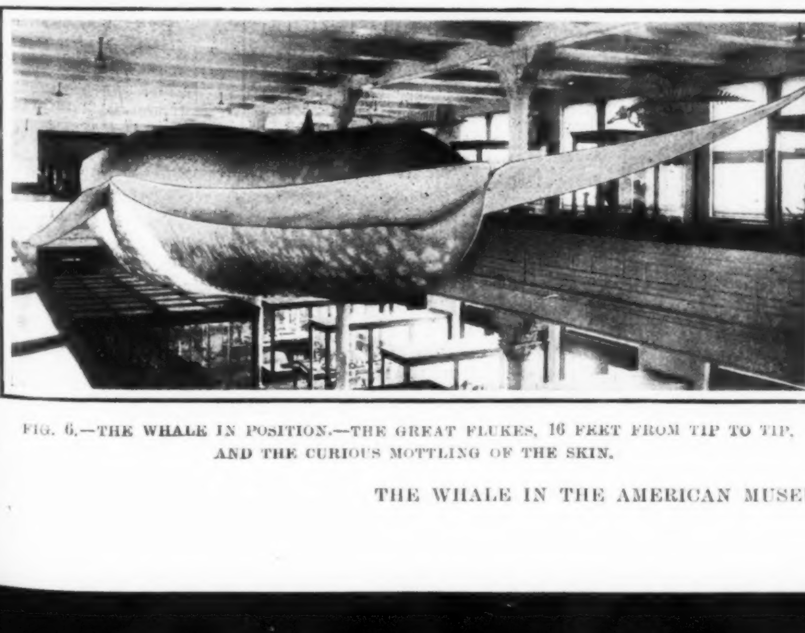


FIG. 6.—THE WHALE IN POSITION.—THE GREAT FLUKES, 16 FEET FROM TIP TO TIP, AND THE CURIOUS MOTTLING OF THE SKIN.

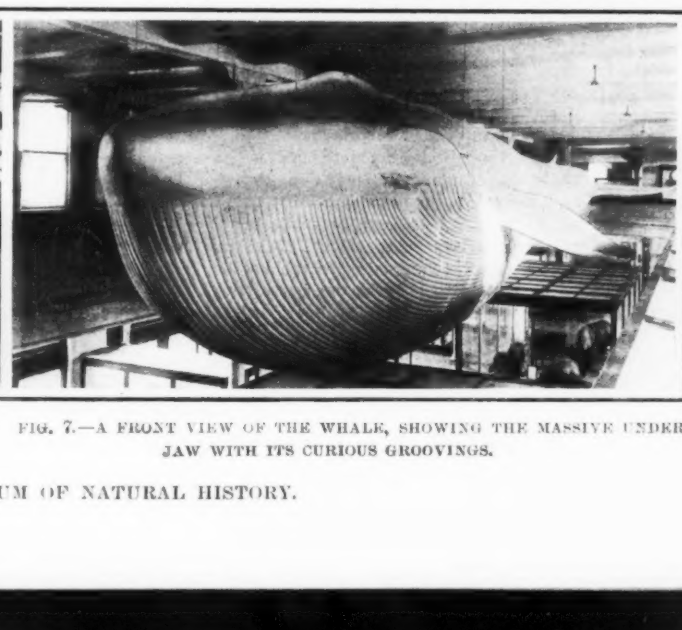


FIG. 7.—A FRONT VIEW OF THE WHALE, SHOWING THE MASSIVE UNDER-JAW WITH ITS CURIOUS GROOVINGS.

THE WHALE IN THE AMERICAN MUSEUM OF NATURAL HISTORY.

THE WHALE IN THE AMERICAN MUSEUM OF NATURAL HISTORY.

A LIFE-LIKE MODEL OF THE LARGEST LIVING MAMMAL.

THE American Museum of Natural History in New York has recently added an exact model of a large whale to its mammalian collection, and the achievement is one deserving of more than passing notice or credit. Relics of whales are common, from the huge jaws to be seen in many a seaside village to the more or less complete skeletons in museums. But there have been obvious difficulties in the way of preserving complete specimens. Not only is there the practical problem of large size, but the oily skin is almost impossible of natural-appearing preservation.

This model is the outcome of a notable forward movement in the policy of the museum. The old formula for "stuffing," say, a bear, was arsenical paste, wire, and a bale of hay. The skin was literally "stuffed" to a barrel-like distortion, and the whole labor cost but a few dollars. To-day the skin is mounted over a model, the work of a sculptor who knows anatomy, and the final result may represent weeks of skilled labor. But it is a correct representation of the animal as it lived.

When it was decided to add a whale model to the collection, the one idea was to obtain a satisfactory fac-simile of the real creature. The species chosen was the sulphur bottom, a whale which is common off the coast of Newfoundland, where regular shore stations are maintained for its chase. This whale is the largest species known, and is indeed larger than any of the reptilian monsters of geology, of which actual traces have been found. The work was placed in the hands of Mr. Roy C. Andrews, of the museum staff, who visited Newfoundland, and was fortunate in securing his data from a large whale measuring 76 feet.

From these data an exact model was made, scale one inch to one foot, and from this model the large one was plotted. The model was divided into sections, and its various dimensions accurately copied on paper ruled in squares. From these plans others of life size were enlarged for the use of the blacksmith, the carpenter, and other workers. The work was done in the large gallery where the whale now hangs. A working platform was constructed, and on this light T-irons were laid out to mark the backbone and the ventral lines (Fig. 1). This framework was bolted together with plates to allow it to be divided into sections of eight feet each, for transportation if required. This provision, however, proved unnecessary, as the finished whale now swings over the spot where its lines were laid down. Rigidity was given to the frame by cross bracing (Fig. 2); and iron ribs were next added (Fig. 3). These ribs, like the back and ventral lines, are accurately bent to the size and contour of the finished model, but are a little smaller; the final covering of laths being carried on a wooden framework fitted over the iron and projecting about a couple of inches beyond it. Up to the stage when the iron ribs were attached to one side, the model was lying on its side. Ropes were now rove through the rings in the ceiling, placed to bear the finished whale, and the framework was raised until it stood upright, resting on the platform. The second set of ribs was now added, giving the complete skeleton shape (Fig. 4). The iron frames for the fins and the flukes were next bolted on, and a wooden framework fastened over the skeleton. On this framework laths were nailed (Fig. 5). These laths were of basswood, two inches broad, and 3/16 inch thick; they were laid diagonally across the skeleton, and this wood was chosen as being soft and bending well to the framework. The framework being now completed, there remained the most important part of the work, from the public's point of view—the outer modeling and coloring. The final outer skin is of *papier maché*. The whale was covered with wire screen of a mesh rather coarser than that used for windows in summer, and the *papier maché* was worked into this.

At this stage Mr. Andrews had the collaboration of Mr. J. L. Clark, the sculptor-anatomist of the museum. To Mr. Clark is due the external modeling, each detail of which is a close copy from life. The wonderful grooves along the lower jaw of the whale—grooves the use of which is not definitely known—are exact in number and position. The blowhole (just behind the hump on the head), the line of the meeting jaws, the tiny external orifice of the ear, and the curves around the eye, were a few of the details needing exact care. The modeling completed, there remained the coloring, and here the thoroughness which has characterized each stage of the construction has been maintained. The body color of the whale is a light slate flecked with peculiar markings. Why the whale received its name "sulphur bottom" is not apparently known, but there is no trace of sulphur color in these fleckings; they circle the hinder parts of the body in patches of a lighter gray slate, and under the belly beneath the film they emerge into an almost solid band of white—as though the whale had been whitewashed. The blotches have been applied with an airbrush, and are successful in suggesting a local lack of coloring matter in the skin, rather than a wash of paint. Figs. 6 and 7 give a good idea of the completed specimen, and of the successful modeling and coloring.

The size of the gallery where the whale hangs allows visitors to obtain a good idea of the proportions of the monster, but handicaps the photographer. The two pictures reproduced show this limitation, and so a few dimensions may be added. The total length of the whale is 76 feet, and its greatest body breadth, across the shoulders just behind the blowhole, is 12 feet. At this point its girth is 36 feet. From tip to tip across the flukes measures 16 feet.

The weight of the original whale was estimated at 63 tons—8 tons of blubber, 8 tons of bones, 40 tons of flesh, and the blood, whalebone, and viscera accounting for the remaining 7 tons.

The sulphur bottom whale attains the largest size of any species, and the longest authentic record of length is 86 feet; this model therefore fairly represents the size of the largest living creature. Off the coast of Newfoundland several hundreds are captured annually. Watch is kept on shore, and when a whale is sighted, a small steamer starts in chase. The captured whale is towed ashore, where in several places machinery has been installed for cutting up the carcass. Little goes to waste; the blubber yields oil, and parts of the viscera are turned into leather. The flesh and the bones are used in making fertilizer, and the whalebone has many uses, although that supplied by the sulphur bottom is not of the best quality.

HEART WEIGHTS OF VARIOUS ANIMALS.

THE RELATIVE SIZE OF THE HEART IS A MEASURE OF METABOLIC ACTIVITY.

BY DR. RABES.

IN all the more highly organized animals the agent of metabolism is the blood, which absorbs oxygen in its passage through the lungs and dissolved nutriment in the walls of the intestinal canal and distributes them to every part of the body, from which it also conveys all waste products to the organs of excretion. The quantity of new material, and consequently the volume and rapidity of the supply of blood, required by an organ are proportional to the work performed by that organ.

Hence in violent exertion the heart's action may be accelerated from the normal seventy to more than 120 beats a minute. As the work of the heart is augmented by increase in the total metabolism of the body, we should expect the size and weight of the heart, relatively to the size and weight of the body, to be approximately proportional to the activity of the animal. This is the fundamental idea of Prof. Hesse's book "Metabolism and the Heart," which gives the results of many careful determinations of the heart weights of all classes of vertebrates.

In the following digest the relative heart weight is expressed in thousandths of the weight of the whole body. Thus, if an animal weighs 1,000 pounds and its heart weighs 2 pounds, the heart weight is given as 2.

The larger the surface of the body, the greater is the loss of heat by radiation and transpiration. Hence, other things being equal, a small animal, as it has a relatively larger surface than a large animal, should also have a greater (relative) heart weight. This law is well illustrated by growing animals. In rabbits the heart weight is 5.85 at birth, 3.91 at the age of two weeks, and only 2.74 at maturity. The heart weight of a newly hatched chick is 9.1, that of a full-grown hen 6.3. The same law applies to nearly related species and breeds with similar habits of life. Three species of ducks of average body weights of about 14, 27, and 34 ounces have relative heart weights of 10.9, 9.8, and 8.5. The heart weight of the common mouse is 6.85, that of the great migratory rat only 4.0.

But in cold-blooded aquatic animals, whose bodily temperature differs little from that of their environment, the relative heart weight is found to be, as we should expect, almost independent of size and relative extent of surface. This is shown very clearly by fishes.

Seven specimens of ray (*Raja asterias*), whose weights varied from 5 to 39 ounces, had the same relative heart weight, about 1.0. Five sea devils (*Lophius*), weighing from 9 ounces to 37 pounds, showed heart weights of about 1.1.

Animals of equal size but of unrelated species show great differences in heart weight, which are due to differences in activity. Magpies, kestrels, and sparrow hawks are nearly equal in weight, but their heart weights, in the order given, are 9.3, 11.9, and 17.0, the sparrow hawk being the best flyer and the most active of the three birds.

For the same reason domesticated animals have smaller heart weights than their wild progenitors, as is illustrated by the following examples of heart weights: Wild duck, 8.5; domestic duck, 6.3; wild rabbit, 3.2; domestic rabbit, 2.8.

In general, the hearts of birds are heavier than those of mammals of equal size, a fact which seems to indicate that flying is harder work than walking or running.

That birds have more active metabolism than mammals was demonstrated by Lavoisier, who found that two sparrows consumed as much oxygen as a guinea pig of many times their weight. The exceptional case of the ermine whose heart weight, 11.8, is but little smaller than that of the equally heavy sparrow hawk, 11.9, is explained by the great activity of the ermine. Another interesting fact is the discovery that the heart weight of the water wagtail, 19.2, greatly exceeds that of the chimney swallow, 14.5. The birds are about equal in weight and the chimney swallow is the more active of the two, but its work is made easy by the admirable construction of its flying apparatus.

The largest relative heart weights are found in birds, the maximum, 24.1, being attained by the sandpiper (*Actitis hypoleucus*), while the highest relative heart weight, 14.4, found among mammals is possessed by the dwarf bat known as *Vesperugo pipistrellus*.

The great loss of heat occasioned by the mode of life of aquatic warm-blooded animals, including birds, finds quantitative expression in their heart weights, which exceed those of terrestrial mammals and birds. A young Greenland whale showed a relative heart weight of 5.7, equal to those of the vastly smaller camel, man, and mole.

For the same reason the relative heart weight of the crested grebe (*Podiceps cristatus*), 10.8, and that of the merganser (*Mergus merganser*), 12.4, greatly exceed those of the eagle, 6.7, and hawk, 8.6.

The smallest relative heart weights are found in cold-blooded animals, as fishes expend energy only in moving, not in supporting the body which floats in the water, and reptiles probably derive part of the energy required for existence from the direct rays of the sun, to which they expose themselves so freely. *Sphagebranchus* and *Ophisurus*, two eel-like fishes which lie motionless in the sand awaiting their prey, have the minimal heart weights of 0.15 and 0.32. The heart weights of the more sluggish pelagic fishes vary from 0.67 to 0.75, while those of the vigorous swimmers *Trachurus* and *Pelamys* of the mackerel family are 1.6 and 2.1, respectively. The heart weight of the blind worm is 1.5; that of the hedge lizard 2.2.

Among amphibia the species which live chiefly in the water have relative heart weights smaller than those of the more terrestrial species, which lose much heat by evaporation from their ever moist skins. Thus, the heart weight of the water toad, 2.8, is smaller than that of the common toad, 3.2, and a similar difference is shown by the water frog, 1.9, and the grass frog, 2.7. Among nearly related amphibia of similar environment the smaller forms have the higher relative heart weights, for example: tree frog 4.8, toad 3.2, grass frog 2.7.

Prof. Hesse, therefore, appears to have proved his thesis, that the relative size of the heart is a measure of the activity of metabolism in the vertebrates.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Prometheus.

THE CONNECTION BETWEEN PHYSICAL AND PSYCHICAL CONDITIONS.

AN EXPERIMENTAL INVESTIGATION.

BY DR. O. MUELLER.

ALTHOUGH the distinction between the body and the soul is as old as human thought, philosophers are not agreed concerning the nature of the difference. To some, the outer world of phenomena appears separated from the inner world of feeling by a gulf that cannot be bridged. This is the dualistic conception. To others this discontinuity is repugnant and they strive valiantly to bridge the chasm. These, the monistic philosophers, are subdivided into two schools: the materialists, who seek to explain psychical as well as physical processes by motion of material particles, and the idealists, who regard the physical world as an illusory reflection or projection of the human consciousness, the Ego. As human experience does not furnish evidence competent to decide this controversy, the decision does not concern the man of science but must be left to metaphysics, that is, to speculation. In this light the observed facts recorded below are to be regarded.

In addition to those bodily movements which are called "voluntary," various bodily phenomena which are clearly involuntary accompany violent mental excitement. The blush of shame, the distinctive flushes of joy and of anger, the pallor and sweat of fear, the tears of grief, and the "creeping" of the flesh provoked by horror, are familiar examples. The respiration is quickened by joy, and retarded by anxiety, and the feeling of relief finds expression in a deep sigh. Violent emotions often disturb the digestion. The heart "bounds with joy," "is paralyzed by horror," "leaps to the throat" in terror. The connection between the heart and the emotions is so intimate that the heart was long regarded as the seat of the soul.

Most of these involuntary physical concomitants of mental excitement are brought about by a special part of the nervous system, the sympathetic nerve and its branches which ramify to every part of the body. The best known branches are those that govern the dilatation of the blood vessels, which is profoundly affected by mental states. These phenomena are susceptible of exact quantitative determination by means of the plethysmograph.

This apparatus consists of a wide glass or metal tube, closed at one end, and connected by a long rubber tube with a flexible diaphragm attached to a lever which moves a pencil on a recording cylinder driven by clockwork. The arm is inserted into the large tube and a rubber band is slipped over the arm and the mouth of the tube, making an airtight joint. The tube may be filled with air or water. In either case every variation in its fluid contents and therefore every variation in the dilatation of the blood vessels of the arm is recorded in the cylinder. When the subject is sitting quiet and undisturbed the pencil traces a nearly horizontal, slightly undulating line, of which each undulation corresponds to a respiration or a heart beat. Now, if an unpleasant sensation or emotion is induced in the subject the line slopes sharply downward, indicating diminution in the quantity of blood in the arm. An agreeable sensation or emotion produces the opposite effect.

In the course of the last twenty years, a great many experiments of this character have been made by many investigators and have led to substantially identical results. I have made hundreds of such experiments on myself and others, always with the results mentioned above.

The method of experiment should be adapted to the character of the subject. In many cases the feeling of pleasure can be aroused by offering a coin or other gift. At the moment of presentation the line traced by the pencil bends sharply upward, indicating a sudden rush of blood to the arm. Then if the gift is taken away, with the explanation that it was presented in jest, the blood vessels contract and the line turns downward. Similar results are obtained by giving students favorable or unfavorable reports of examinations, reading poems to persons of fine sensibilities, etc.

The results are especially striking when they are not expected by the experimenter. My examination of a farmhand was interrupted by the unannounced visit of a government inspector. Under the influence of astonishment the veins of the subject's arm quickly contracted and the trace on the cylinder turned downward. A well-known physiologist performed a similar experiment in honor of a royal visitor.

There are great differences in the intensity of the physical effects of various mental processes. Difficult tasks in mental arithmetic, performed in private, cause only slight contraction of the blood vessels of the arm, but the same calculations made in the presence of several persons, especially persons regarded with awe, cause great contraction. In general, emotional excitement, which common experience proves to be more fatiguing than purely intellectual activity, also affects the plethysmograph more strongly.

The fluctuations of the supply of blood according to the mental state can be observed also in the leg, and in the brain in a person who has been deprived by accident of a portion of the skull, so that part of the brain is covered only with skin. The changes in the brain and in the limbs occur sometimes in the same direction, sometimes in opposite directions.

The Italian physiologist Mosso has devised another method of studying the variation of blood supply in the brain. The subject is laid on a board which is balanced on a fulcrum at the center of gravity. Agreeable sensations and emotions cause a depression, disagreeable thoughts an elevation of the head, by affecting the supply of blood to the brain. Falling asleep and waking produces analogous results.

I have modified this method by placing the subject on a fixed table with his head resting on the pan of a balance. The results agree with those obtained with persons with fractured skulls, but it is very difficult to avoid the disturbing effect of small voluntary movements.

In regard to changes other than those in blood supply numerous experiments with self registering apparatus have shown that, in general, unpleasant feelings deepen and retard the respiration but accelerate and weaken the heart's beat, while pleasure makes the respiration more rapid and less full and the pulse fuller and slower. Other feelings and emotions produce their specific effects in like manner and so each psychical state is accompanied by a characteristic group of physical symptoms. It has been suggested that these symptoms may betray the carefully guarded feelings, emotions, and general psychical conditions of criminals and insane persons, though some physiologists question the value of the results so obtained.

Aside from these practical applications, however, the discoveries that have been made are very important. Like many other modern discoveries they are not absolutely new. Variations in the pulse were regarded in antiquity as indications of mental perturbation. Nearly 2,500 years ago Erasistratus, by feeling the pulse of the son of King Antiochus in the presence and in the absence of his young and charming stepmother, successfully diagnosed the young prince's puzzling malady as an "affection of the heart."

Severe bodily pain is commonly attended by alterations in the pulse and the pupil of the eye. This method of ascertaining whether a patient's suffering is as acute as he pretends was introduced by French physicians centuries ago.

The influence of mental states on digestion is particularly interesting and important. Until a few years ago it was thought that the stimulation of the glands of the mouth, stomach and intestines when food is taken was caused by mechanical irritation alone. Then Pawlow discovered the great influence of psychical impressions on the flow of digestive juices. His experiments were made with dogs, but physicians often observe similar phenomena in human patients and many puzzling empirical discoveries become clear when regarded from Pawlow's point of view.

Pawlow found that the mere sight or smell of meat provoked a copious flow of gastric juice in dogs, and that the sight of less appetizing food, such as bread, induced only a slight secretion. He distinguishes two secretions, one due to mechanical irritation by food, the other induced by the psychical phenomenon of appetite before the food is taken into the mouth. For perfect digestion the co-operation of both secretions is required or, in other words, only appetizing foods are thoroughly digested.

The saliva, besides assisting directly in the digestion of starch, moistens and lubricates the food and makes it easier to swallow. Liquid food given to an animal provokes a very small, dry food an abundant flow of saliva. If, however, a few pebbles are put into a dog's mouth they will soon be rejected without having caused any appreciable salivation. Sand, on the contrary, induces a copious flow which serves to wash away the sand that adheres to the mucous membrane. This could be explained by mechanical irritation, but the mere sight of sand causes salivation in a dog that has been subjected to this experiment so often that it has acquired a knowledge of the unpleasant properties of sand.

A similar experiment may be made with acids which also stimulate the secretion of saliva. If a dog's tongue is painted with vinegar which has been colored black or red, the animal associates the color with the acidity and thenceforth the sight of black or red ink causes salivation. That the sight and smell of appetizing foods provoke a flow of saliva in the human subject is a well known fact that finds expression in the phrase to "make the mouth water."

The disturbances of the circulation caused by emotions are most pronounced in nervous and abnormally excitable persons. A sudden fright or slight annoyance often produces a rush of blood to the head while the hands and feet become ice cold. In other cases blood rushes to the heart or causes local swellings of the skin. If the patient is removed to an environment devoid of every cause of excitement and is not tormented by too persistent attempts to convince him that nothing is the matter with him the morbid irritability, in most cases, gradually subsides. Then, if he is very gradually accustomed to the slight annoyances and shocks which are unavoidable in ordinary life, he may be restored to a perfectly normal condition.

Many of the diseases of the alimentary canal are of nervous origin, and are largely due to the hurry and worry of modern life. Men come fatigued to the table and eat without appetite. Their food disagrees with them and chronic dyspepsia soon follows. They are so occupied with the cares of business that they scarcely know what they are eating, and appetite, which is another name for pleasant expectation, is excluded from its proper place in the bodily economy. Probably that part of the gastric secretion which is induced by appetite is very deficient and therefore digestion can not be perfect. These things have long been known practically, and we have been cautioned not to eat immediately after hard physical or mental labor, but the reason of the caution is only now becoming understood. The taking of food is a matter of sufficient importance to require a condition of mental calm so that interest and appetite may be awakened.

It should be noted in this connection that articles of food which are strongly disliked are not easily digested. Milk affords a striking example. Although it is one of the most valuable of foods it is disliked and ill digested by many, especially nervous persons. Physicians are still divided on the advisability of insisting on a milk diet for such patients, but there is an increasing tendency to respect the preferences of the patient as far as possible and to exclude from the diet articles that are repugnant to him.

Thus many things learned empirically by the physician at the sickbed are confirmed by the experiments of the physiologist in his laboratory. The practician and the investigator are mutually dependent, for in some cases clinical practice suggests problems for solution while in others experiment points the way to the cure of disease.—Translated from Umschau.

To Copy Transfer Ink Without a Press and Without Moistening the Paper.—Dissolve 30 parts of aniline color in 2,000 parts of water containing 15 parts of alum mixed with 100 parts of glycerine. It suffices to place the written sheet between two leaves of a letter copying book, to obtain a copy, which is accomplished after a few minutes, without any pressure, provided the letters are in perfect contact with the leaf on which it is desired to make a copy.

To Harden Stamped Steel Objects.—Such pieces, for the most part, possess elasticity, which is the greater the more uneven their cross-section, and to remove this elasticity the objects must be heated to redness without exposure to the air. For this purpose, the pieces are placed in pots, boxes, closed pipes, etc., surround them with sufficient amounts of finely broken charcoal, close the lids, if necessary make air-tight with fireproof clay, and then the heating to redness can be commenced, after which the closed vessels are set aside and allowed to cool slowly. The hardening process proper now begins, which consists in immersing the steel pieces in water until the red glow disappears, then taking them out quickly and plunging may also be used, and in this case the steel is left until completely cooled. Instead of oil, boiling water may also be used, and in this case the steel is left to cool gradually from inside outward.

THE AIR OF THE NEW YORK SUBWAY.*

AN IMPORTANT PROBLEM IN VENTILATION.

WHAT was perhaps the most exhaustive study ever made of a single problem of ventilation has recently been concluded for the Rapid Transit Railroad Commission of New York by Dr. G. A. Soper, consulting engineer of New York.

The investigation was begun in July and extended to January, 1906. It concerned the existing conditions in the subway. Some idea of the thoroughness with which the investigation was made may be gained from the fact that there were about 2,200 chemical analyses of air, 3,000 determinations of bacteria, and about 400 other analyses in special studies of dusts, oils, disinfectants, and other substances. About 50,000 separate observations of temperature and humidity were made prior to the adoption of a system for automatically and continuously recording the temperatures. The average number of investigators continuously engaged under Dr. Soper's direction was ten.

The remedies recommended, so far as any remedies were found to be needed, were simple and chiefly in the line of prevention. In reference to cooling, the Commission was advised at the outset to provide more and larger openings between the subway and the outside air.

HOW THE SUBWAY BREATHES.

The length of the road, about 21 miles, and the rather wide variety of conditions which occurred in it, made it desirable to confine the investigation as far as practicable to a representative section. There was no difficulty in selecting this section. The road between 96th Street and the Brooklyn Bridge was, in every respect, the most important. The length of the section was about 6 miles. The cubic air space included was, in round figures, 26,100,000 cubic feet, including the stations.

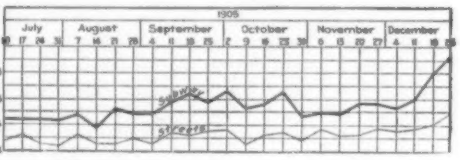


Fig. 1.—Weekly Average Carbon Dioxide for the Subway and Streets from July 10 to December 25, 1905, Including 1,772 Determinations.

aggregate, two hours and thirty-five minutes, made at eight stations, it was calculated that an average of 573,000 cubic feet of air had moved in and out of one stairway per hour. This was at the rate of 9,500 cubic feet per minute.

That the air circulated freely from one station to another was shown by carbon dioxide analyses (to be

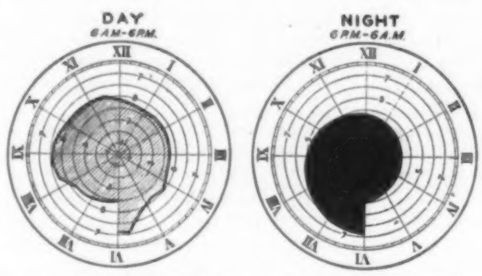


Fig. 2.—Hourly Variations in the Amount of Carbon Dioxide in the Air of the Subway. Average of 1,214 Analyses.

referred to later) and by noting the time it took an odor to pass from one station to another. Cologne of a highly concentrated grade, and in sufficient quantity to produce a distinct perfume throughout the air of a station, was atomized on several occasions and the odor noted up and down the line by observers with stop watches.

As a result of eight experiments, it was found that the air was carried from station to station at the

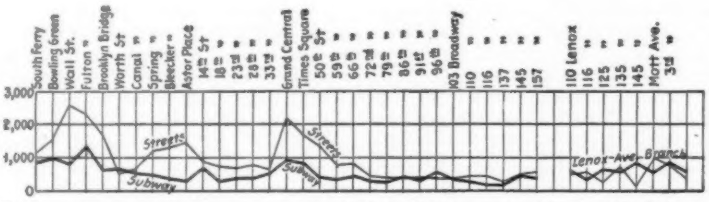


Fig. 3.—Average Number of Bacteria which Settled from the Air upon Each Square Foot per Minute at Different Subway Stations and in the Streets. The Number of Samples Represented is 2,753.

the subway on the approach of a local train and is replaced by an indraught of fresh air as the train draws away, we have what physiologists, in speaking of the ventilation of the lungs, call the "tidal air." In the additional quantity which is drawn in by the express trains, we have the "complemental air," and in the excess which is forced out by express trains the "reserve or supplemental air."

These three, the tidal, complemental, and supplemental, Dr. Soper terms the "respiratory or ventilating capacity" of the subway.

Finally, there is an amount of air which remains in the subway and is not immediately forced into the streets by any combination of local and express trains; this is called the "residual air."

TEMPERATURE AND HUMIDITY.

Throughout the investigation the subway was warmer than the streets. The only exceptions were when the outside temperature rose rapidly after a prolonged low period. This usually occurred in summer in the middle of the day, and in winter after a cold snap.

The excess of subway temperature over outside temperature increased considerably during the autumn and winter months beyond that noted in summer. In the early part of July the difference between the temperature for the whole day inside and outside of the subway was less than 5 degrees. In the latter part of September it was over 10 degrees. In January it was at some stations about 20 degrees.

The temperature in the subway for the daytime for July and August, combining the records of these two months to form an average, was 82.4 degrees; it was

The subway was ventilated through the stairways at the stations and through blowholes in the roof. All of the blowholes were located in that portion of the road which lay above 60th Street. They were rectangular in shape, and opened upon small grass plots which occupied the center of the wide boulevard known as Upper Broadway. Iron railings surrounded the openings. To prevent the entrance of large objects, the openings were covered with coarse wire netting.

The blowholes were located above the center of the railway, one being situated a little beyond each end of each station. An additional blowhole was placed midway between each two stations above 59th Street. The total number of blowholes between 59th and 96th Streets was eighteen. Each was about 7 x 14½ feet in the clear. Wire nettings, beams, and other objects took up about one-quarter, or more, of this space.

The stairways between the streets and the stations varied somewhat as to width and direction. South of 59th Street they were usually placed at right angles to the line of the road; north of 59th Street they were parallel to the road. There were usually two stairways, each in cross section about 5½ x 7½ feet, to each local station above 59th Street, and eight narrower ones to the other local stations.

Exchanges of air between the subway and streets were caused by the movement of the trains. The subway was about 50 feet wide and 18 feet high on the four-track section between Brooklyn Bridge and 96th Street. The cross section of a car occupied about 14 per cent of this section. The trains were from 150 to 408 feet long.

As a train moved through the subway, air was forced ahead of it and air followed it. As a rule, a general current flowed along the track on each side in the direction of the train movement, and these currents continued even when no train was within hearing distance.

The movement of the air depended upon the speed of the nearest train, the movement of other trains in the vicinity, the size and location of the neighboring openings to the outside air, the size of the particular cross section of the subway with reference to the position of the stairways, the difference in temperature inside and outside of the subway, and other conditions.

Observations with anemometers were made at a number of stations on several occasions. As a result of seventy-nine of these observations, covering, in the

average rate of 271 feet per minute, or about 3.03 miles per hour.

The ventilation of the subway bears an interesting resemblance to the ventilation of the human lungs. In each case ventilation is due to currents of air passing inward and outward as a result of changes of pressure, caused chiefly by the expansion and contraction of the inclosed space. It is true that with the

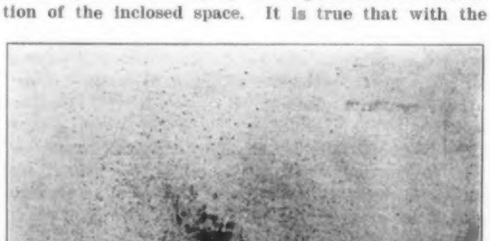


Fig. 4.—Magnetic Field Formed by Subway Dust.

lungs the size of the inclosed space is alternately enlarged and reduced through the movement of its walls, while in the subway the size of the inclosure is increased and diminished through what is termed the piston action of the trains; but in other respects the similarity is close.

In the normal amount of air which passes out of

76.8 degrees outside; difference, 5.6 degrees. The highest temperature observed in the subway during the investigation was 95 degrees. This occurred at the Brooklyn Bridge station, July 18, 1905, at 3.50 P. M. The lowest temperature was 30 degrees. The outside temperature at the same time was 14 degrees, giving a difference of 16 degrees.

The coolest, vest ventilated, and most agreeable stations were those which were most open to the streets.

The relative humidity in the subway was generally less than that out of doors. The humidity varied with that outside. The average relative humidity for the subway for July and August was 57.5 per cent; for the outside air, 60.6 per cent; difference, 3.1 per cent. The greatest average humidity occurred during the week when the average temperature was highest. During this period it was 64.4 per cent.

CHEMICAL CONDITION OF THE AIR.

The chemical analyses of air were chiefly confined to determinations of carbon dioxide, for no other test could give such a correct knowledge of the extent to which the air was vitiated by respiration, and none could be made on a large scale with so little probability of error.

The carbon dioxide analyses produced results which have been summarized by Dr. Soper as follows: The average amount of carbon dioxide in the subway was but little larger than in the streets. The average of all results was, for the subway, 4.81 volumes per 10,000 volumes of air, and for the streets, 3.67; difference, 1.14. This difference must be regarded as very slight. (See Fig. 1.)

The greatest amount found in the subway was 8.89. This occurred in the tunnel between the Grand Central station and the 33d Street station, on December 27, 1905, at 6:02 P. M. At this time trains were stalled at all points in that vicinity. At the adjoining stations of 33d Street and Grand Central, the carbon dioxide was higher than usual at the same time, the amount at 33d Street being 7.84 and at Grand Central 7.87.

The amount of carbon dioxide varied in the subway at different hours of the day. (See Fig. 2.)

These irregularities corresponded with the irregularities in the amount of travel which took place at different hours.

In the subway the greatest amount for the whole day occurred between 5:30 and 6 P. M. Thereafter, there was a gradual fall to the lowest point, which

* Abstracted from a paper in the Technology Quarterly, March, 1907.

was reached between 3 and 4 A. M. From the lowest point the amount increased steadily to about 9 A. M., after which it fell irregularly to between 1 and 2 P. M. The average for the whole day agreed closely with the average between 1 and 3 P. M. In the late afternoon there was a rapid rise to the maximum for the day, which was reached at about 5:30 P. M. The difference between the least and greatest amounts of carbon dioxide was, according to these hourly averages, 2 parts per 10,000.

There was more carbon dioxide at express stations than at local stations except at the especially open express station at 96th Street. Among the principal express stations, the largest average amount was found at 14th Street. Then came the Brooklyn Bridge, Grand Central, 72d Street, and 96th Street stations, in the order named. There was more carbon dioxide between stations than at the adjoining stations, although in most cases this difference was very slight. The results of 442 analyses showed this average difference to have been 0.18 part per 10,000 with a range of from 0.29 to 1.72.

Marked differences occurred in the amount of carbon dioxide, found at points above and below 50th Street. The average of all results demonstrated that the air from 50th Street uptown was much purer than the air from 50th Street downtown.

The average amount of oxygen found in the air of the streets was 20.71 per cent; in the subway, 20.60 per cent; difference, 0.11 per cent. The least amount found in the subway was 20.25 per cent. There was therefore always an abundance of oxygen.

BACTERIAL CONDITION OF THE AIR.

Bacteria were collected by allowing them to settle from the air for fifteen minutes upon circular plates, or Petri dishes, 3½ inches, or about 9 centimeters, in diameter, containing a standard agar culture medium, and by collecting them from the air by means of sand filters.

A careful examination of the data collected in these studies led Dr. Soper to draw the following conclusions:

There were, on an average, more than twice as many bacteria found in the air of the streets as in the air of the subway, excepting after rains, when fewer were found outside than inside.

The average numbers of bacteria which settled from the air in fifteen minutes, and were subsequently enumerated, were, in the subway, 500; outside, 1,157; difference, 657. (See Fig. 3.)

The average number of bacteria found by filtering the air was 3,200 per cubic meter in the subway and 6,500 in the streets; difference, 3,300.

The molds recovered from the air by filters were almost always less numerous in the subway than out of doors. The maximum number of molds found was 1,100 per cubic meter. This observation was made in the tunnel under Central Park.

The average ratio of molds to bacteria, as determined by the observations with filters, was 1 to 40 in the subway.

The wind in the streets had a decided effect upon the numbers of bacteria collected from the air, inside as well as outside of the subway. Five times as many were recovered from the air of the streets with a wind of 18 miles per hour as with a wind of 9 miles.

No attempt was made to identify the different kinds of bacteria. To have named the species would have been beyond the practical limits of bacteriological technique. Nevertheless, the conclusion was reached by careful indirect studies that most of the bacteria came from the streets.

Although it seemed likely that most of the bacteria in the air of the subway were derived from the streets, there was ground for concluding that some, and among them objectionable kinds, were due to the presence of the people. It was practically certain when great crowds were packed together, as they often were in the subway, that dangerous bacteria were, at least occasionally, transmitted from person to person. An obvious feature of this danger lay in the fact that people talk, cough, and sneeze into one another's faces at extremely short range under such circumstances.

The numbers of bacteria in the air of the subway varied with the amount of travel. They were most numerous when the trains were most numerous, and fewest when the trains were fewest. When the trains were blocked, many of the bacteria disappeared from the air. In one case the bacteria were reduced from 1,300 to 250 in about an hour in this way. This is shown in Table I.

It was suspected that harmful germs might be capable of multiplying in the oil which dripped from the machinery of the cars upon the broken stone ballast and wooden ties of the roadbed, but it was found that the lubricating oil removed and collected from the air large numbers of bacteria, many of which soon ceased to exist.

The pneumococcus was found capable of retaining its virulence in dried sputum in the subway for twenty-three days, whereas it was killed in four hours in sunlight.

With few exceptions, there were not so many bacteria in the air of the toilet rooms as in the rest of the subway, but in some cases the numbers were much greater. Proprietary disinfectants used in the toilet rooms had no germicidal or deodorizing value and were thoroughly objectionable.

The numbers of bacteria recovered from dust from the subway averaged 500,000 per gramme. The largest number of bacteria found was 2,000,000 per gramme. Still greater numbers probably could have been obtained by selecting the specimens of dust toward this end.

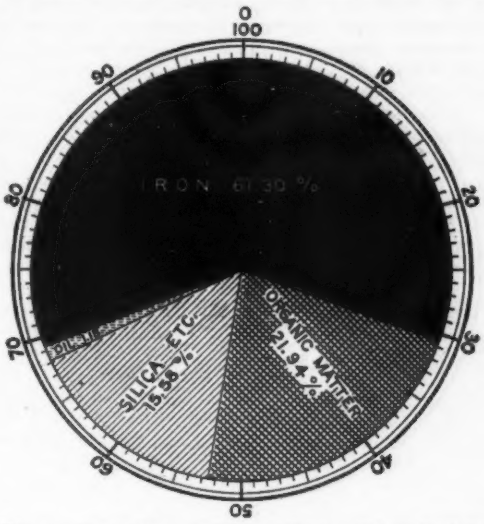


Fig. 5.—Composition of Subway Dust as Determined by Chemical Analyses of Eleven Samples.

For comparison with the numbers of bacteria found in subway dust, it was interesting to note that dust from a Broadway theater contained 270,000 bacteria; from a new and fashionable hotel, 360,000; from a well-known Fifth Avenue church, 320,000; from the tallest office building in the city, 850,000; and from the attic of a country house one hundred and fifty years old, 110,000 bacteria per gramme.

Dusts which had accumulated in the subway contained over twice as many molds as dust collected in outside buildings. The ratio of bacteria to molds was 89 to 1 for the subway and 250 to 1 elsewhere.

ODORS.

Unpleasant odors were more or less prevalent at all times and at all places in the subway. In some cases they were so faint as hardly to be noticeable, in others very decided.

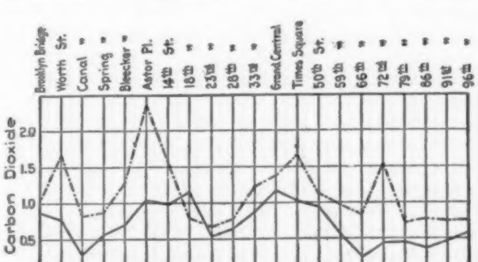


Fig. 6.—Relation Between the Chemical Condition of the Air in the Subway and the Ratio of the Effective Area of the Openings to the Cubic Contents of the Air Space at Different Stations.

The effects of these odors upon the passengers varied with the sensitiveness of the individual. To some the odors were exceedingly offensive, to others they were barely noticeable; many passengers soon became used to the odors and did not notice them.

The odors were most apparent during hot, damp weather, at places where the greatest crowding occurred and where the least amount of ventilation took place. Very offensive odors were more often noticeable in the cars than elsewhere, especially in the fall and winter months, when the windows were closed and the number of passengers was unusually large.

The following conclusions were, in Dr. Soper's view, justified by these studies:

The stone ballast of the roadbed was responsible for much of the odor. This stone was made of broken traprock, and its peculiarly slaty odor in the warm atmosphere of the subway was unmistakable.

The oil used in lubricating the wheels and machinery of the cars was also a principal cause of odor. Large quantities of this oil, composed chiefly of petroleum and fish oil, were allowed to drip from the machinery upon the ballast and ties of the roadbed. In the first six months of operation there was probably wasted in this way over 25,000 gallons on the whole road. In addition, about 150 pounds of gear grease were used per mile per month.

Much of the oil and grease was heated by the bearings, and volatilized, the car journals, motor armature bearings, and motor axle bearings sometimes being raised to a temperature of from 100 to 170 deg. F.

That the oil was distributed through the atmosphere of the subway was fully demonstrated. It was recovered from the dust by extraction with ether to the extent of 1.18 per cent by weight.

Hot boxes, of which there were a considerable number when the road was first put in operation, at times produced a persistent and suffocating odor. Wool waste was used in packing the car journals, and when this caught fire its unpleasant smell could be distinguished through the subway for a long time. Occasionally a fuse was blown out and its odor distributed up and down the line. When a fire occurred, as happened on a few occasions, the odor of smoke persisted in the part of the subway where the fire occurred for a surprisingly long period of time. In one case the odor was distinctly noticeable to passengers, as the cars passed the spot, three months after the fire had taken place.

The odor of tobacco smoke was not uncommon at the subway stations. Rules existed against smoking in the subway, but they were not enforced. Lighted cigars, cigarettes, and pipes were occasionally carried even into the cars. Odors of human origin were sometimes present, but almost always close to people. They were most common during warm, damp weather, and where there was much crowding. These odors often came from the clothing of the passengers. It was sometimes possible to learn the occupation of a workman by the odor of his clothes. Odors of coffee, garlic, bad teeth, liquor, cheese, and perfumery were some of the personal odors noticed. In fact, under the conditions of crowding amounting frequently to close personal contact, it seemed that odors of practically every character connected with human existence were noticeable.

Excepting in rare instances, where ignorant employees were not kept under as strict supervision as their defective sense of decency required, the odors which permeated the general air of the subway did not point to conditions dangerous to health.

DUST.

The dust was examined microscopically, chemically, and bacteriologically, by a special method which was devised for determining the gross weight of dust in a measured volume of air, and by an instrument for estimating the total number of floating particles present.

It was possible, by means of a common horseshoe magnet held beneath a piece of paper sprinkled with the dust, and slowly moved from side to side, to distinguish particles of iron and steel. These metal particles could be made to rise on edge and reverse their position by changing the pole of the magnet presented to them.

In appearance the dust was always black and very finely powdered. It was easily distinguishable by the eye from dusts collected in the streets, and in theaters, churches, office buildings, and mercantile and manufacturing establishments.

The dust had a peculiarly adhesive character, which caused it to attach itself securely to all surfaces, even when these were vertically placed and glazed. All parts of the subway which had not been recently

Table I.

Effect on the Numbers of Bacteria in the Air of the Subway Produced by a Blockade Lasting an Hour, November 11, 1905

Place.	Time.	Micro-organisms per Cubic Meter of Air.	
		Bacteria.	Molds.
110th Street and Broadway station, north end, east platform. Soon after the collection of the first sample all trains stopped running. Finally, no passengers in subway	10.20*	1,300	0
	10.37*	750	0
	10.55*	400	0
	11.15*	250	0
Average	..	700	0

cleaned and painted, or were not of a dark color, were sprinkled with this black dust when the investigation began.

The dust had a marked capacity for soiling linen and other articles of clothing. Straw hats and the light-colored garments worn by the passengers of both sexes in summer were likely to be soiled by coming in contact with even small accumulations of the dust.

When examined microscopically, the dust was found to be composed of particles of many substances, conspicuous among which were fine, flat plates of iron. In fact, these iron particles could often be seen with the naked eye, glistening upon the hats and garments of persons who had been riding in the subway.

Particles 2 millimeters long were, on one occasion, taken from a magnet which had been carried in the hand on a ride of twenty minutes in the cars. By comparison, it was found that magnets hung up in the subway collected more particles of iron than magnets of the same size and strength hung up in an iron foundry or a dry grinding and polishing establishment. Fig. 4 shows a magnetic field formed by subway dust.

Particles of subway dust, not iron, comprised bits of silica, cement, stone, fibers of wood, wool, and cotton, molds, and indistinguishable fragments of refuse of many kinds.

The separate chemical analyses of eleven samples of accumulated dust from the subway showed the following average percentage composition: Total iron, 61.30, including 59.89 metallic iron; silica, etc., 15.58; oil, 1.18; organic matter, 21.94, as shown in Fig. 5.

A large part of the metallic iron came from the wear of the brake shoes upon the steel rims of the wheels of the cars. The wear upon the brake shoes was very severe. By weighing them when they were new and after they were worn out, and determining the number used, it was calculated by the operating company that one ton of brake shoes was ground up every month for each mile of subway.

There was also some loss to the rails and rims of the wheels and to the contact shoes which ran upon the third rail. Probably 25 tons per month would be a low estimate of the weight of iron and steel ground up in the whole subway every month.

The average weight of dust found in the subway was 61.6 milligrammes per thousand cubic feet of air, or 2.25 milligrammes per cubic meter; in the streets, 52.1 milligrammes per thousand cubic feet, or 1.83 milligrammes per cubic meter; difference, 9.5 milligrammes. The maximum was 204 milligrammes.

The weight of dust which the average passenger inhaled in one-half hour in the subway must have been very slight. Assuming that 360 cubic centimeters, or 22 cubic inches, of air were taken in at each breath, and that the passenger breathed eighteen times per minute, the total quantity of air which passed into the lungs in half an hour was about 6.88 cubic feet, or 0.19 cubic meter. If the weight of dust suspended in the atmosphere is taken at 61.6 milligrammes per 1,000 cubic feet of air, it appears that the average passenger took into his nose or mouth 0.42 milligramme of dust in a ride of half an hour.

The stations where the greatest weights of dust were found were express stations; there the amount of metallic dust formed by the braking of the trains was much greater than at the local stations and the travel from the streets greatest.

FINAL CONCLUSIONS.

A review of the results of the investigation warranted, in Dr. Soper's opinion, the following conclusions:

1. According to usual sanitary standards, based on chemical and bacteriological analyses, the general air of the subway was always and everywhere satisfactory. The air of the cars in winter is not included in this statement.

2. According to public opinion, based on the testimony of the senses, the air was everywhere unsatisfactory, and it was especially unpleasant during the summer months.

3. Dr. Soper's opinion was that the general air, although disagreeable, was not actually harmful, except, possibly for the presence of iron dust. The strong drafts in winter at the stations and the lack of sanitary care exercised over the subway were, however, worthy of careful consideration in this connection.

4. The high temperature of the subway was its most noticeably objectionable feature. Had it not been for the heat, it was probable that the other unpleasant features would have failed to arouse serious protest. The heat, as is well known, was due to the conversion of electric power into friction. The amount of heat given off by the passengers was so small by comparison as to have had practically nothing to do with elevating the general temperature.

5. The heat was most objectionable in the mornings and evenings of summer during the hours of greatest travel and when the outside was cooler than during the rest of the day.

6. The heat did not indicate that the air was vitiated or stagnant, as was popularly supposed. The subway was hot because a great deal of heat was produced in it, and stored by the materials of which the subway was built. That the heat did not escape rapidly enough for comfort was no proof that the air was not renewed often enough for health.

7. The carbon dioxide and oxygen analyses indicated that the products of respiration were rapidly carried away. Among the 2,200 carbon dioxide determinations, most of which were made in the subway, no sample of air was found which contained above 8.89 parts of CO_2 per ten thousand volumes, and this amount was found under circumstances which must be regarded as exceptional.

8. The average excess of carbon dioxide in the subway over that in the streets, 1.14 parts per ten thousand volumes, showed that the air was renewed with remarkable frequency. In the absence of a census giving the number of passengers in different parts of the subway at different hours, it was impossible to calculate just how frequently the air was renewed; but from such estimates as it was possible to make it seemed not improbable that the air of the whole subway was completely renewed at least every half hour.

9. It was true that the renewal of air occurred somewhat more frequently in some parts of the subway than in others, but the exchange was always and everywhere abundant. We must except, of course, from this statement, the cars when closed, and other places where dense crowding occurred.

10. The controlling condition which regulated the extent to which the air was renewed was the freedom with which it could move in and out of the subway. The air was best where the subway was most open to the streets, and, conversely, it was least satisfactory where the subway was most inclosed. This could be shown by diagram. (See Fig. 6.)

11. The movement of the trains set in motion the essential ventilating currents. This they did, first, by forcing subway air out and bringing street air in at the openings; and second, by moving the air through the subway between openings.

12. It was fully demonstrated that there were no pockets or other places where air stagnated. Diffusion was everywhere rapid, complete, and satisfactory. The cars are excepted in these statements, as already indicated.

13. The fact that there were only about half as many bacteria found in the air of the subway as in the air of the streets under which the subway ran gave ground for the opinion that the bacteriological condition of the subway air was satisfactory, although too much reliance should not be placed upon this guide to its condition. Judgment on this point would have been more conclusive had it been possible to demonstrate that no more harmful bacteria existed in the subway than in the air outside. This was beyond the practicable possibilities of bacteriological technique.

14. The odors of the subway, like the heat and dust, were objectionable, apparently, chiefly because they were disagreeable. They resulted largely from the operation of the trains. They were, to a large extent, preventable and should be prevented.

15. The sanitary significance of the characteristic black dust of the subway, containing, as it did, over 61 per cent of metallic particles, remained to be considered at the close of the investigation.

THE RISE AND TENDENCIES OF GERMAN TRANSATLANTIC ENTERPRISE.

A RECORD OF PROGRESS.

BY PROF. ERNST VON HALLE, PH.D.

THERE was no German traffic beyond the seas to speak of before the formation of the United States. The consequent disruption of the colonial system produced lively trade relations during the ensuing period of French revolutionary wars. After a short interruption, produced by the "continental system," a second impetus was given by the establishment of other independent states in South and Central America, 1815-1830.

The abolition of the colonial system in the rest of the European colonies marks the third phase of expansion, and the opening of trade relations with Eastern Asia; commercial treaties with Japan and China the fourth. Preceding the formation of the German Empire there existed a very limited commerce with Africa. By 1871 German tradesmen and bankers, particularly sons of the Hanseatic towns, were to be found in all parts of the world.

A few German merchant princes and a larger number of small tradesmen abroad not only maintained relations with their country, but also handled the traffic of other commercial nations.

London was the money market, and to some extent the money lender. On the other hand, a large share of German transatlantic exports and imports passed through English warehouses, and more still in English bottoms. The political decentralization of the country had for centuries left the majority of German states without seaports and seafaring interests. The Zollverein brought commercial unity to the interior and Baltic sections, but did not embrace the North Sea ports till after the three wars which gave the empire a flag and a commercial policy.

At this time the population, which had doubled since 1800, numbered 42,000,000. In the next thirty years 20,000,000 more were added; 65,000,000 live to-day where about 20,000,000 lived at the close of the Napoleonic wars. Besides the increasing population, three events—the opening of the grain fields in North America, the introduction of iron and steel steamers into the transatlantic freight service, and the rise of large industries in Germany after the war—were the chief cause of the country's transition from a grain-exporting nation into a grain-importing nation by the middle of the seventies. The industrial crisis increased the protectionist tendencies among the manufacturers, while American competition turned the agriculturists to protectionism. But the new economic policy did not stand in the way of rapidly increasing imports, which had to be paid for by increasing exports.

It was not the manufacturing interests that nourished exports, but rather the demand of a growing population for food supplies and industrial opportunities of employment. Up to this time transatlantic enterprise had been of a somewhat incidental significance for German national economic life; it now became vital. Larger exports of merchandise and capital for foreign investment, the establishment of large commercial fleets, insurance and cable companies, now became necessary to meet the increasing requirements of the importing interests. By inaugurating a colonial policy in 1884 Bismarck meant to crown the process of empire making.

The censuses of 1882 and 1895 show a remarkable transformation in the economic structure of Germany. Unable to employ a larger number of people in its pursuits, agriculture had thrown the full surplus population into industrial occupations. The agricultural classes in 1815 numbered about 18,000,000, about the same as a hundred years ago, while the industrial population had increased 600 per cent. The standard of life had improved throughout, chiefly in the middle and lower classes; but in spite of the introduction of scientific methods, agriculture was unable to keep pace with requirements.

By 1900 one-fifth to one-fourth of the foodstuffs, and more than nine-tenths of the raw material for clothing, etc., had to be imported. Had not a rapid development of foreign trade and rising foreign investments closely followed the resulting necessities, either starvation, or emigration, or foreign war would have resulted.

To avoid a precipitated industrialism and a dangerous decline of agriculture, the country decided upon an increase of agricultural protection. Germany's geographical position will always necessitate an ample agricultural resource at home to avoid the dangers of starvation in war times. It was compelled to sacrifice some of the industrial possibilities of tariff treaties to this point of view.

The situation to-day is that Germany's foreign commerce amounts to $3,750,000,000, of which $2,125,000,000 are imports.

Of the difference, fifteen to twenty millions are made up in the earnings of German shipping, the rest in the interest from foreign investments, consisting of $2,250,000,000 investments in transoceanic countries, $4,000,000,000 foreign stocks and bonds (of which more than $500,000,000 are transoceanic), and more than $1,250,000,000 other investments.

Of the imports, about 40 per cent come from over the sea outside of Europe, while of the exports a little

less than 25 per cent go to foreign continents, more than 30 per cent of its trade.

With neighboring countries Germany exchanges more than 40 per cent.

The trade with the United Kingdom amounts to about 20 per cent of exportation and 14 per cent of the importation, and with the British Empire 24 per cent of exportation and 22 per cent of importation. While England has ceased to be paramount in German transatlantic trade, it still holds the first rank. Of the commerce of the world, incoming and outgoing, the three leading countries, England, Germany, and the United States, to-day control not less than 40 per cent in either direction. Of this a large share is transacted among these three countries.

German exports have not increased as rapidly as the demand for imports. The foreign investments are rising in importance. They may become the leading feature by the time that machine-using industries have become more extended in tropical and sub-tropical countries.

Germany will be compelled to improve its commercial and industrial processes, its means of transportation, and its business organization to keep pace with foreign competition. The real dangers of the competition of the future are neither to be found in England nor in Germany, nor even in the United States, though this latter country makes a more rapid progress than the former two. They will ensue from the working of certain natural laws: increasing populations, increasing demand for the products subject to diminishing returns, and increasing supplies of the products subject to increasing returns.

The political tasks of Germany's future are continental, in consequence of its central position, but her economic tasks will necessarily consist of an extension of every form of her commercial sea interests.—Read before the British Association for the Advancement of Science.

THE PROGRESS OF THE SUBMARINE BOAT.

A CRITIQUE OF RECENT EXPERIMENTS.

THE most fascinating engineering problems of the day are undoubtedly those associated with submarine and aerial navigation; and in view of the number of eager and capable workers, he would be a bold prophet who would deny the probabilities of substantial success in both cases. So far as practical work goes, the application of the submarine boat is likely to take precedence, and be much more extensive at an earlier date, largely because the difficulties are not so great as in the case of flying machines. It is true that there are some who doubt whether the problems of the submarine boat have been definitely solved, and such pessimists point to the many accidents, more or less serious, that have happened as justification for their misgiving. These accidents, however, are not inherent to the system, but are such as should be classed as incidental to all innovations. On the other hand there are, from time to time, many evidences of success; and however much all deplore the loss of life in submarine boat accidents, few will regard them as deterrents to that experimental work essential to continued progress.

A suggestive report has been issued by the special board appointed by the United States Navy Department to make searching tests as to the mechanical efficiency of different types of submarine boats. This action was in connection with the vote of $3,000,000 made by Congress for expenditure on new craft during the current year. Congress further voted a large sum for experimental work, so that the tests undertaken might be of a comprehensive character. Three designs were submitted. One of these was of the Holland type now so widely approved in nearly all the important navies of the world, and the generic type from which our very successful British boats have been evolved. The actual boat submitted for test was the "Octopus," a vessel of 273 tons displacement, built by the Electric Boat Company, of New York, and launched in 1906. It represented the latest conception of this design of boat. The Lake Torpedo Boat Company offered for test the submarine boat "Lake." The third design proposed is known as the sub-surface type. As a prelude to our notice of the tests it may be stated at once that the board were unanimous in their preference for the Holland design of boat, which, in a long series of practical tests, proved most satisfactory.

The "Octopus," like the great majority of submarine craft, is driven on the surface by internal-combustion engines, and the consumption is such as to insure that, with a fuel storage supply of 4,000 gallons, the radius of action will be 700 miles. Electric motors are used for propulsion when submerged. The surprisingly good speed of 10.03 knots was realized as a mean of three measured-mile runs with the conning tower of the vessel 10 feet under the surface. This is a splendid performance. On the surface the maximum speed was 11.57 knots, and the mean 11.02 knots. As regards diving, the vessel went down at an angle of 8 deg. to a depth of 26 feet within 40 seconds; she immediately returned to the surface, remained there under observation for five seconds, and dived once more. The complete evolution was carried out in about a minute and a half. This facility of disappearance is of the greatest importance from the point of view of fighting efficiency, and the result is, therefore, most interesting. Again, the time taken to disconnect the gasoline engines and to couple the electric motors was only 12 seconds, five seconds for the former and seven seconds for the latter operation. As to maneuvering, the vessel, when awash, made a complete circle in 3 minutes 40 seconds, the diameter of the circle being about 200 yards. Running on the surface, with only one screw, she made a half circle to starboard in 1 minute 35 seconds, and a half circle to port in 2 minutes 40 seconds; in the latter instance the screw propeller was working against the rudder. Going full speed ahead when awash, the vessel was able to reverse her direction of propulsion in 52 seconds. As to endurance, the boat was required to remain 24 hours submerged at a depth of 200 feet, and it was computed that only one forty-fifth of the total air supply was exhausted, which suggests a long radius of action under water so far as the air supply is concerned.

The Lake boat also did well in remaining under water for this lengthy period, but in the other tests the "Octopus" proved superior. The Holland boats are fitted with an automatic device for blowing out the tanks when submerged, in order that the vessel may rise to the surface from any predetermined depth, for which the apparatus is set to come into action. The mechanism was set to be effective at 40 feet, and when this depth was reached 30 tons of water were blown out of the ship in 18 seconds, the total time taken for the test, including the immersion of the boat, being 48 seconds. Another important trial was made in connection with submarine bell signals from the "mother" ship, and by this means it was possible for the commander of the fleet to communicate to the various vessels when submerged. It was also found that wireless telegraphy could be used on the "Octopus" when on the surface and awash. The masts were 30 feet high, and the antennæ, 50 feet long, consisted of four strands of wire. Under these conditions it is anticipated that the range of communication will be 40 miles.

These facts, which were evolved by the government tests, again prove the practicability of submarine navigation, which has frequently been demonstrated, although actual data have been withheld. The data further establish the efficiency of the Holland type of submarine boat, and "that she is equal to the best boat now owned by the United States or under contract." The results suggest that a larger boat than the vessel referred to, which is of 273 tons displacement, would be a superior weapon. As to the Lake type of boat, the Commission report: "1. That the type of submarine boat as represented by the 'Lake' is, in the opinion of the board, inferior to the type as represented by the 'Octopus.' 2. The closed superstructure of the 'Lake,' with the large flat deck which is fitted to carry water ballast, and to contain fuel tanks and air flasks, which is an essential feature of the Lake boat presented to us for trial, is inferior to the arrangement on board the 'Octopus' for the same purposes, and also, in the opinion of the Board, is detrimental to the proper control of the boat. 3. The hydroplanes, also an essential feature of the Lake boat presented to us for trial, were incapable of submerging the boat on an even keel. They are, therefore, regarded as an objectionable incumbrance."

As regards the design known as the sub-surface type of boat, the Commission very properly reported that it could not be compared with submarine boats, being of an entirely different type. In this class of boat the machinery, magazines, and habitable quarters are inclosed in a submerged hull, from which there is communication to a surface hull through conning towers or armored tubes, the two hulls being joined, pretty much like the booms of a girder, by web plating or cellular structure. The surface hull is utilized only for the accommodation of the guns and the gear for controlling propulsion and navigation. In other words, what would be considered the upper deck of an ordinary ship is separated from the sub-structure, with the exception of tubes of communication, so that in action damage to the upper part would not affect or endanger the lower hull with the machinery and magazines. The system is ingenious, but is, as the Naval Board point out, analogous to the torpedo boat or torpedo-boat destroyer. The sub-surface boat does not afford that advantage of invisibility which is the great desideratum met by submarine craft, and therefore its potentiality for damage is not so great. There was only submitted to the Board a quarter-size model, and consequently it was impossible to make a satisfactory comparison, even with the performance of torpedo boats and torpedo-boat destroyers. The Commission, however, point out that so far as their observation went there was no reason to doubt that the guarantee made as to speed, etc., would not be carried out. The sub-surface boat is less vulnerable than the torpedo boat, requires fewer men, and has a larger steaming radius, but she has less speed and greater draft. The president of the Commission, Capt. Adolph Marix, took exception to the general pronouncement that the tests of the sub-surface boat model "did not develop that boats of this type, built of a size suitable to render their qualities available, are equal to the best torpedo boats now owned by the government." In the opinion of the captain, the smallest size of sub-surface boat fitted with a regular torpedo-tube, and built to give a speed of 15 knots, would be a weapon of great value, additional to any now owned by the government, and this value could be enhanced by the rapidity with which they could be constructed, and the ease with which they could be transported.

The Board were not called upon to pronounce as to the strategical or tactical advantages of the submarine boat. This was scarcely necessary in view of the general consensus of opinion in all admiralties in favor of the type, and the large number now being built by the various powers. In the recent Dilke return it was shown that there are already in existence 117 vessels of a submarine type, and that there are building 86; while the programmes of many powers, in addition to the United States, anticipate very considerable additions. Great Britain has 37 completed and 11 on order, and the size has steadily advanced from 122 tons displacement to something approximating to 400 tons, the power of the machinery having increased in the same period from 160 to 800 horse-power on the surface, while the power of electric motors for propulsion under the surface has increased from 70 brake horse-power to well over 200 brake horse-power. These vessels, as we have already indicated, have been evolved from the Holland type, and long experimental research has been carried out, with the result that no dubiety exists as to the efficiency of the type, while at the same time there is achieved that homogeneity which is so important in the training of the *personnel* to secure a sufficient supply of men during action, and to maintain the highest efficiency, which is dependent on thorough experience in these vessels more than in any other. France has forty boats completed, and fifty-nine are in course of construction. Here there is great diversity of opinion as to the best type of vessel, and the boats vary in size from 21 to 560 tons displacement. The tendency, however, is all in favor of vessels of large size, most of the boats under construction being of about 400 tons displacement. Russia has twenty vessels completed, and has on order eight. Germany has moved more slowly in this matter, but she has completed her first vessel, and has two building; her estimates for the next three years provide about $1,750,000 for submarine construction. Italy has four vessels building, and two in course of design. Japan has seven built, while the United States have in commission eight vessels, and four in course of completion, all of the Holland type. Now there is every prospect of this type also being utilized for that important addition to the submarine fleet which was anticipated by the appointment of the Naval Board whose report we have reviewed.—Engineering.

The following is the color scheme adopted in the power plant of the Pennsylvania, New York & Long Island Railroad Company in Long Island City, N. Y.:

White—High-pressure steam lines.

Bright red—Drips from superheated steam lines, including the Holly system and connection to boilers.

Bright red with black flanges—Saturated steam lines and Holly system connection.

Yellow—Exhaust from auxiliary apparatus and low-pressure drip lines.

Black—Boiler feed piping from boiler feed pumps to boiler drums, including heaters, economizers, and their connections.

Blue—All water piping, except the boiler feed lines and fire lines.

Structural color—Fire protection system; painted to match the structural steel to which it was adjacent.

Maroon—Blow-off piping.

Green—Air lines.

Slate—Crank case oil piping between engines and separators.

Brass—Unpainted, all oil lines except those painted slate color.—Engineer.

THE AEROPLANE EXPERIMENTS OF M. LOUIS BLERIOT.

A RÉSUMÉ OF WHAT HAS BEEN ACCOMPLISHED TO DATE IN FRANCE WITH AEROPLANES OF VARIOUS TYPES, INCLUDING THAT INVENTED BY PROF. LANGLEY.

BY CAPT. FERBER.

M. Bleriot is an example of what tenacity and perseverance in attaining the realization of one idea can accomplish. The story of his experiments is, for the philosopher who knows or the young man who wishes to succeed, a new proof that it is possible to arrive at the end sought, after having overcome all obstacles.

In 1900, as all minds were turned toward the future, M. Bleriot constructed a flying machine, and without advice or without going very deeply into the principles, he built it after the type which seems the most natural to all tyros in this new science; that is, on the orthopter or flapping-wing principle. Wings containing valves were moved up and down by means of a carbonic-acid-gas motor. He soon discovered the difficulties met with in a machine of this type, the chief of which is the method of moving the wings. Nevertheless, it is to be noted that this machine contained an arrangement which is found in all his future models. This is a universally-jointed control mechanism, which permits the tail to take any desired position in the air.

The difficulties which Bleriot encountered caused him to stop work until 1905, when the new movement toward aviation, started at the Aero Club by M. Archdeacon, caused him to begin anew. At this epoch, when the light motor did not yet exist, everyone was experimenting along the line of soaring flight, which at least gave the aviator a good training in the management of an aeroplane. M. Bleriot designed a machine, and had it constructed in the Surcouf workshop by young M. Gabriel Voisin, who at this period was experimenting for M. Archdeacon. On account of the arrangement between the latter two men, the experiments made at that time were generally credited to them by the press, and nothing was heard of M. Bleriot as an aviator. The machine, towed on the Seine by the motor boat "Antoinette," showed lack of stability, and M. Voisin, who was in it when it overturned, narrowly escaped drowning. There is a good cinematographic record of this test.

From this time on, M. Bleriot wished to have his own means of construction, and consequently he, at the beginning of 1906, purchased from M. Surcouf the part of his workshop in which he built flying machines. Afterward he was joined by M. Voisin, and together they founded the first factory for the construction of aeronefs, or heavier-than-air machines. Being now furnished with the means of building machines, he designed a cellular type of aeroplane having elliptical cells, and mounted it on floats for the purpose of testing it on the Lake of Enghien (Fig. 5). As at this time the light "Antoinette" motors had begun to make their appearance, he furnished this aeroplane with a 24-horse-power motor, and arranged it to drive two propellers in opposite directions. (Fig. 5).

He next encountered the complication of transmission devices and the difficulty of making solid propellers; that is to say, he met with the same difficulties which stopped, and which will stop for a long time, the construction of the rival type so dear to many experimenters, viz., the helicopter type. Finally M. Bleriot recognized also the grave defects of starting on the water, which caused the complication and the extra expense of pontoons, and which generally resulted in damage to the machine that it is very difficult to repair.

Moreover, Santos Dumont had just proved that it was possible to start from the ground and land again without danger, and that the complication of two propellers was unnecessary. M. Bleriot then completely changed his tactics. He separated from the Voisin establishment, which was continued in business under the name of Voisin Frères, and established himself in a fully-equipped workshop near the Porte Maillot. Here he gave himself up completely to the construction of his machines.

FIG. 1.—BLERIOT'S SECOND AEROPLANE IN WHICH THE FORWARD ELLIPSE OF THE FIRST MACHINE WAS REPLACED WITH PARALLEL PLANES.

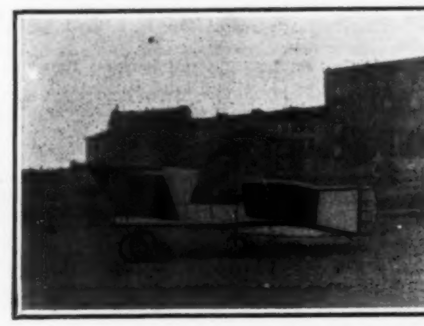


FIG. 2.—THE LANGLEY-TYPE MACHINE WHICH HAS MADE A NUMBER OF SUCCESSFUL FLIGHTS.

Note the auxiliary controlling plane on the end of the forward plane.

He first started on an aeroplane which was quite different from his former ones. (See Figs. 3 and 4.) This machine was a monoplane, and consisted of a single pair of wings, having a spread of about 25 feet and a surface of 140 square feet. The wings were attached to the rear end of a central body, which carried at its forward end both horizontal and vertical rudders. These had a surface of about 5½ and 2½ square feet respectively. They were operated from the aviator's seat by means of suitable levers. The motor, which was placed directly back of the aviator, carried on its crank-shaft a two-bladed propeller, 1.6 meters (5¼ feet) in diameter, and having a variable pitch which could be regulated from the operator's seat. An indicator showed the operator the speed of the motor at all times. With a pitch of 0.98 meter (3¼ feet), and a speed of 1,300 R.P.M., this propeller gave about 176 pounds thrust. It was calculated that a speed of 37 miles an hour should cause the machine to lift, but unfortunately it did not fulfill expectations.

The first trials were made with this aeroplane at the beginning of the present year, but the wings, which carried Bleriot and his motor in the body part of the machine, were decidedly unstable. Perhaps, if he had modified this machine by adding a tail, he would have succeeded in making it more stable; but, after scrapping the whole machine, M. Bleriot started to build his fifth aeroplane, which was modeled entirely after that of Prof. Langley, and which is a type that is known to be sufficiently stable.

The experiments with this machine, which were begun two months ago, were at first completely negative, the 24 horse-power developed by the motor not being sufficient to turn the propeller of 1.8 meters

FIG. 3.—FRONT VIEW OF MONOPLANE MACHINE, SHOWING RUDDERS AND POSITION OF OPERATOR.

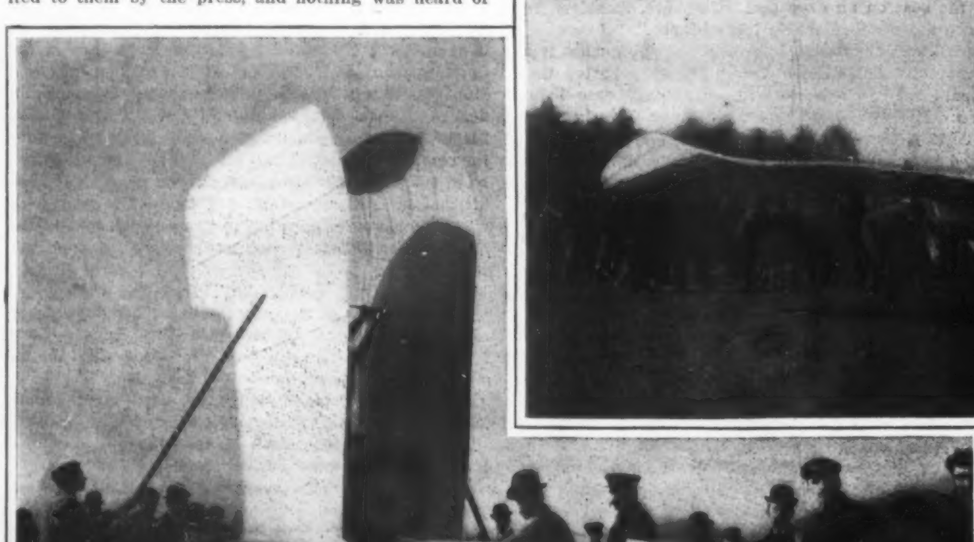


FIG. 4.—ATTACHING THE PLANES TO THE BODY OF BLERIOT'S MONOPLANE FLYING MACHINE.

The planes consisted of parchment paper tightly stretched over suitable framework.

THE BLERIOT AEROPLANES.

(5.9 feet) diameter and 1.4 meters (4.59 feet) pitch. Following the advice of the writer, he diminished the pitch with good results. He found it advantageous to make the pitch as low as 0.9 of a meter (2.95 feet), in order to allow the motor to speed up and develop its full power.

From this time on, every trial of the machine was a step in advance. On July 11 he made a flight of 30 meters (98½ feet) and found that the lateral stability was perfect. On July 15 he tried the machine against a wind of at least 6 meters (19.68 feet) per

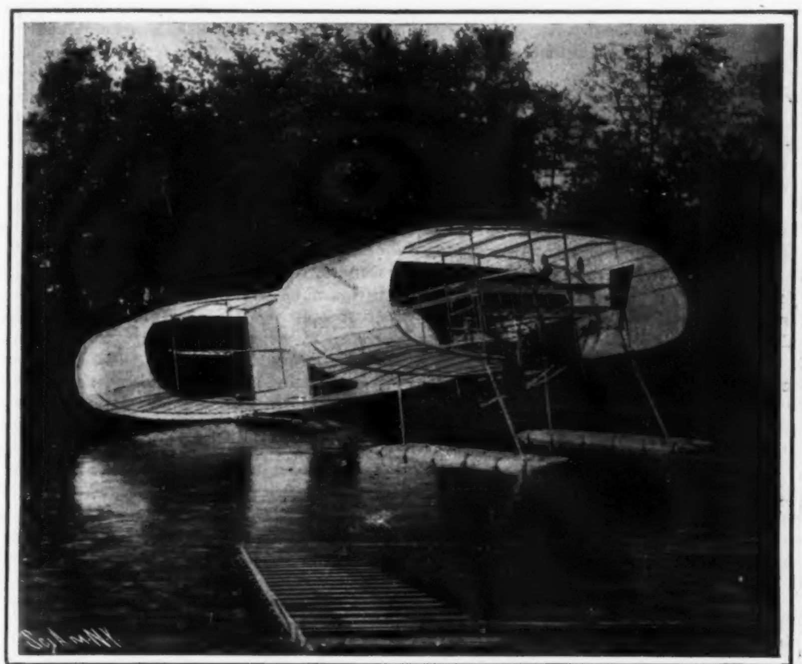


FIG. 5.—FIRST ELLIPTICAL TYPE AEROPLANE MOUNTED ON ITS PONTOONS.

The operator was seated back of the forward ellipse with his feet upon bars that control the double horizontal rudder in front. The two propellers were driven by an 8-cylinder gasoline motor of 24 horse-power through bevel gears and flexible shafting.

second, and covered a distance of about 80 meters (262½ feet). He found in this trial that the aeroplane was too heavily loaded at the rear, because, at the end of the flight, it stopped very abruptly when the speed was being checked. It made some unsteady movements up and down at the height of about 15 feet. Instead of stopping the motor, as reported in the newspapers, he, on the contrary, increased the spark advance too much for the speed at which the motor was running. This stopped the motor, and the aeroplane struck the ground head downward, smashing the front wheels and the propeller. Its audacious pilot was not injured.

On July 24, after repairs had been made, the aviator tried again. This time he had moved his seat forward about 80 centimeters (31½ inches) in order to remedy the defect in balance. Evidently this was too much, for this day he was unable to make a flight, as the rear part of the machine alone would rise.

Nevertheless, he was near the proper point of balance. M. Bleriot next arranged his seat on small wheels, as in a racing scull, and on the 26th of July he made a first flight of 120 meters (393.7 feet) by starting first with his seat well at the back and then, after he had got in the air, by moving his seat forward.

Thus it will be seen that in place of using the horizontal rudder he displaces the center of gravity, as did Lillienthal; but when once the angle of attack has been established, he remains stationary and does not budge. All that he has to do then is to rise or fall by speeding up or slowing down his engine.

The most important gain on the last day was a turn which he made. While making a second perfect flight, he suddenly found himself at the end of the field, and decided to work his vertical rudder. With striking precision the aeroplane started to turn in a circle like a large bird, making a curve of about 200 meters (656 feet) radius, its inner side tipping downward like a bicyclist making a turn. At the end of the turn he was traveling with the wind at a very high speed, and there was probably a slight downward current, which forced him to touch the ground, but the machine did this gently without shock, and simply ran along on its wheels.

This is the farthest M. Bleriot has advanced at the present writing. He holds in his hands a complete solution of the problem, and consequently, after having made enough trials to become expert, he will be ready to compete for all the prizes of the Aero Club. He will, nevertheless, do well to make use of the horizontal rudder, for the effect produced by the displacement of the center of gravity, however efficacious it may be, is a very difficult and delicate method of controlling the machine.—La Nature.

THE LANGLEY-TYPE AEROPLANE OF M. BLERIOT AND SOME OF ITS PERFORMANCES.

The first test of M. Bleriot's new Langley-type aeroplane occurred at 5 A. M. on July 7 last on the drill ground of Bagatelle, near Paris. The machine was lightened, but to no purpose, as it was unable to get o' the ground, although it showed a tendency to rise in front.

M. Bleriot spent several days after the first test in remedying this defect of stability. He also increased the surface of the supporting planes (which appeared to be insufficient) from 18 square meters (193.75 square feet) to more than 20 square meters (215.28 square feet). The weight of the machine was thus increased to a total of 280 kilogrammes (617.29 pounds), 75 (165.34 pounds) of which represented the weight of the operator. The pitch of the propeller was reduced from 1.1 meters to 0.9 of a meter.

After making these modifications, the machine was tried again on July 11 at 6 P. M., and after running practically 200 meters (656 feet) on the ground, the two front wheels raised about 0.3 of a meter, and were soon followed by the rear wheel. The aeroplane continued in its flight, and at a height of about 2 meters (6½ feet) it covered a distance of from 25 to 30 meters (82 to 98 feet). On account of the crowd which got in the way, M. Bleriot shut off the spark, thus stopping the motor and causing him to alight. In alighting, several of the steel tubes were broken, which made it impossible to experiment further on this day.

It is, nevertheless, true that the Bleriot aeroplane, in addition to those of Santos Dumont, Vuia, and Delagrange, adds another to the short but glorious list of the heavier-than-air machines which have succeeded in leaving the ground under their own power. This first decided success will recompense the ingenious and tenacious efforts of the young engineer, M. Bleriot. We hope to see him obtain still more important results in the near future.

The aeroplane, as can be seen from the photographs, consists of two pairs of wings, set at a slight angle, and placed one pair behind the other on a central body. In general appearance, the aeroplane resembles that of Prof. Langley, but it has several important modifications. The most noteworthy of these consists in the placing of accessory planes, which are movable around a horizontal axis, at the ends of the forward planes. By means of a handle, connected by an ingenious arrangement of levers, the operator is able to vary the angle of incidence of these accessory planes, and thus to cause the machine to be raised or lowered at the front end and on opposite sides. The same handle, when placed in different positions, gives to the two planes an opposite angle of incidence, or it operates one of these planes without affecting the other. The rear planes are entirely rigid. A single propeller on the motor shaft is used in place of the twin propellers employed by Bleriot heretofore. The entire body of the machine is covered with paper for the purpose of reducing to a minimum the passive resistances. The operator is seated in the body part of the machine at about the rear edge of the forward planes. The motor sets just in front of him. At the rear end of the body portion there is a vertical rudder.

After making further experiments on July 15 (which experiments are mentioned below) the inventor expected to do away with the accessory stabilizing planes, as he found it too difficult to operate them by means of the single lever provided, while executing the other movements necessary to control the machine. In place of these planes, he expected to arrange a single plane directly back of the propeller and beneath the forward end of the body part of the machine. This plane he expected to operate by means of a movable seat arranged on small wheels. Thus, by moving his body forward or backward, he varies the center of gravity of the machine, and also its center of pressure, by causing the horizontal rudder at the front to operate.

M. Bleriot has also started the construction of a new aeroplane having two pairs of wings in tandem, and which is to be fitted with a 50-horse-power motor with magneto ignition, etc. This, on account of its great strength of construction throughout, will be considerably heavier than the present model.

Several tests of the machine which we illustrate were made on the 15th of July. In the morning a flight of 40 meters was accomplished, and later in the afternoon, in the presence of several members of the Aero Club de France, M. Bleriot made a flight of 25 meters in a straight line. A third trial, at 6:30 P. M., was still better, for a distance estimated to be 78 meters (255 feet) was traversed in a straight line in nine seconds, which would be a speed of about 19 miles per hour. Little by little, the machine rose to a height of 10 meters, and displayed perfect lateral stability. The flight was made against a wind of about 6 meters per second (14 miles an hour). The operator did not change the accessory equalizing planes. Upon landing, the wheels were slightly damaged.

These results are all the more remarkable in view of the fact that the machine flew with such a small supporting surface and with a relatively small motor of only 20 to 24 horse-power.—The Aerophile.

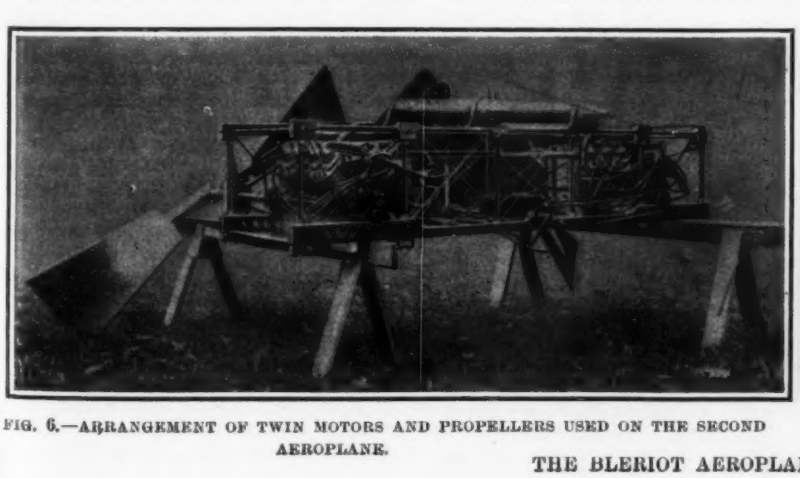


FIG. 6.—ARRANGEMENT OF TWIN MOTORS AND PROPELLERS USED ON THE SECOND AEROPLANE.

FIG. 7.—THE LANGLEY TYPE AEROPLANE IN FLIGHT.

THE BLERIOT AEROPLANES.

THE DEVELOPMENT OF ARMORED WAR VESSELS.—III.

ARMOR PLATING IN THE UNITED STATES

BY J. H. MORRISON.

Continued from Supplement No. 1653, page 152.

STEVENS BATTERY.

The designing of this war vessel was in contemplation some time before making the experiments on the iron armor plates. The high reputation of the Messrs. Stevens as engineers in this country had brought them into contact with prominent officials of the army and the navy of the United States. Some influential officers of the two departments had been sent to Europe to obtain such data as would be of service in the construction of iron vessels, and improved ordnance, after some experiments made there in 1840, that this government might have a naval vessel of advanced type. Gen. Paixhan, a French army officer, had at this time suggested iron armor for naval vessels, to protect them from the effect of explosive shells. The progressive element in our navy and our army advocated with the Messrs. Stevens the building of this experimental vessel, and the department officials considered the latter at this time the most efficient of our constructing marine engineers for working out a plan for a vessel of that type.

This radical departure in type of a war vessel was not the work of Robert L. Stevens alone. Col. George Bomford, U. S. A., had for many years been interested in this subject. This officer had introduced the "Columbiad," a shell or bomb cannon, into the service of our army during the war of 1812, as a seacoast weapon; and Robert L. Stevens claimed the invention of an explosive shell during the same period, the United States government subsequently purchasing the right to manufacture the shell for its own use. Robert L. Stevens carried on some experiments in 1822 at Governor's Island military station in New York Bay, with explosive shells, and at this time Col. Bomford was located on the island as a lieutenant-colonel of an artillery regiment. Col. Bomford was the best-informed officer in the service on the subject of ordnance for many years, and when the Ordnance Bureau of the War Department was created in 1832, he was made chief of that bureau, which place he held for about ten years. There was also Commodore Matthew C. Perry, U. S. N., who was one of the few progressive naval officers of that period. It was this officer who was called the "Father of the Steam Navy," and who was in November, 1852, sent to Japan, in command of the "Mississippi," and joined in Eastern waters by three of our naval vessels, to negotiate a treaty with the emperor of that country. These officers were of marked ability in their respective professions, and their opinions on official subjects had much influence in the departments at Washington at the time. They recognized the change that was taking shape in the type of naval vessels, and their armament, by all the naval powers of Europe, and gave their aid and counsel to the advancement of this new departure. To show that it had for some time been recognized by the government officials, Edwin A. Stevens says: "This whole subject, *previously a subject of conference with the government* [italics the writer's], was treated of in 1841 as then old and familiar, especially to Robert L. Stevens, so that the claim of American priority of invention cannot be invalidated by a French claim in 1846, as some constructors in America have intimated, nor by an English claim in 1858."

When Robert L. Stevens designed this vessel, his experience with the screw propeller was limited to almost the experiments and alterations that had been made with the "New Jersey," and of the four iron-hull screw canalboats built from Ericsson's design for the Delaware and Raritan Canal Company. That was probably as much, if not more, knowledge of the subject than most of our American constructing marine engineers had at the time of the screw propeller. He had experimented with the screw propeller more than thirty-five years before this period, but it was soon laid aside as a means of propulsion for more than one reason. He could not have had a very high opinion of the screw propeller, as he did not fit that means of propulsion to any of his large fleet of passenger boats, they being operated by beam engines and side wheels.

There was an engineer that came on the scene of mechanical activity in this country about two years before the designing of this vessel became publicly known, who had much influence upon the development of our steam merchant marine of that day. That was none other than John Ericsson, the designer of the first successful iron-hull screw propeller in this country, although built in England. When he arrived in this country late in 1839, he had in his professional line the support of Commodore Robert F. Stockton, U. S. N., but this lasted only about four years. In 1841 he designed the machinery for the "Princeton," the first screw armed vessel in the United States navy, and in fact the first screw naval vessel in the world, and this will be noted as the time when Robert L. Stevens was carrying on the experiments with iron armor. Ericsson brought with him to this country a wrought-iron gun, that in some experiments made with it about 1842, in which the shot from this gun penetrated 4½ inches of iron plates, opened the eyes of the United States ordnance officials and the Messrs. Stevens to the fact of the weakness of the proposed armor for their war vessel. This proposed iron vessel was also to be fitted with twin-screw propellers. We thus see at the commencement of the work on the plans of this vessel there was a rivalry between the two interests in their application of the screw propeller on war vessels for the United States navy. This rivalry increased in a few years, involving others who entered the same field, that ended in a lawsuit by a non-professional as to the prior right to a patent on a screw propeller in this country. Robert L. Stevens made a large number of experiments with the screw propeller from 1844, with the single screw, the twin screw, as well as the triple screw. They were carried on at Bordentown, N. J., where the machine shops of the Camden and Amboy Railroad Company were located. The results of these experiments have been well guarded from all publicity, as were almost all their extended experiments on the line of marine engineering. This period was well termed the War of the Propeller.

That the Navy Department was interested in this project, and probably the mainspring of the whole enterprise, is clearly evident from the annual report of the Secretary of the Navy of 1841, where he says: "Under the appropriation of the last session for the purpose of making experiments to test the value of improvements in ordnance, in the construction of steamers and other vessels of war, and in other matters connected with the naval service, and the national defense, nothing has yet been actually paid. Some experiments have, however, been already authorized, and others are now under the consideration of the Department, from which very beneficial results are confidently anticipated. It is not proper, however, to make them public at this time. So many scientific and practical men throughout the country are now turning their attention to this subject, that we may reasonably expect great advantages from a judicious use of this appropriation." The Secretary of War in his annual report of the same year refers more fully to the protection of our coast cities by floating batteries than is usual for that department, showing an interest at the time in the development of an advanced type of war vessel. There was a board at this time called the National Defense Board, composed of officers detailed from the Navy and the War Departments, who were engaged in the investigation of the defenses of our coasts.

The industrial conditions of the country affecting our marine interests, prior to this first iron-armored war vessel, were of such a character that they should be noted before considering the development of iron armor, as they clearly show what questions of engineering and shipbuilding had to be encountered in carrying forward an enterprise of this magnitude.

There had been for ten years prior to 1840 many changes made in the designs of the marine boiler, and during that period the tubular boiler had been brought forward. Sheet copper had been almost universally laid aside, and plate iron used in its stead in the construction of marine steam boilers. Then at the end of this period the independent steam engine was applied to the fan blower, to furnish a blast to the furnace of the steam boiler. The screw-propeller engine began to be constructed about 1841, and the iron-hull steam vessel was in a measure still an experiment in its construction in this country. Two wooden-hull *steam frigates*, the first of that type in our navy, were completed in 1841, and the building of the iron-hull naval steamer "Michigan," for service on the lakes, had just been begun. To add to these many changes in shipbuilding and marine engineering was the revolution in the process of the making of iron in the United States. We had just commenced in 1842 to forge wrought-iron shafts of, at that time, large diameter. The steam hammer had not yet come into use in our forge shops, although Nasmyth had recently introduced it in Great Britain. Our machine shops had been compelled, up to this period, to make all the tools and machines they had in service in their works. The first maker of machine tools, as a separate branch of the iron industry, was John H. Gage, of Nashua, N. H., who started in 1837. This is a long list of changes and developments that culminated about the same time as the first publicity is made of the plan of an iron-armored war vessel. While all these changes were far from a perfected state, still they had shown their worth in passing beyond the experimental stage, and as being worthy of recognition. Their marked progress and improvement a few years later indicates their value at the period named. There were many features in a vessel of such a radical departure as contemplated by Robert L. Stevens in 1841, that would have to be thoroughly worked out to make it a success, and with many of these engineering and shipbuilding questions not thoroughly understood at the time, it was assuming a great risk in embarking on such an enterprise. There was more than one problem of the time he never solved in the experiments for this vessel.

Robert L. Stevens's trip to Europe in 1841 was no doubt taken, partly at least, to ascertain the progress made in iron shipbuilding in Great Britain, for there was then building the "Great Britain," that exceeded 300 feet in length, for Atlantic Ocean passenger service, and two government vessels, each of about 150 feet in length, as well as several smaller than the "Great Britain" for the merchant marine, all iron hulls. John Laird, of Birkenhead, had up to this time constructed more than twenty iron-hull steam vessels.

The first work done in preparing for the design of this proposed armored vessel, of which there appears any record, is given in the following letter, that is published in full on account of its rarity, as are some other letters on the same subject. This letter refers to the first experiments made on wooden and on iron targets, that were comparatively light structures.

To Colonels Totten, Thayer, and Talcott, and Commodores Stewart, Perry, and Smith, of the Navy, who were appointed by the President to superintend the experiments of the Messrs. Stevens on iron as a protection for war vessels, and on Stevens elongated shells.

New York, August 13, 1841.

To the Chairman of the Board of Navy and Army Officers:

Sir: In compliance with the request of the Board that we should reduce to writing the heads of our views on the subject of steamers for harbor and coast defense, etc., as requested by the instructions, we beg leave to state that as our ideas upon the subject have been derived principally from our brother Robert, we cannot but regret extremely that he is not here to give and explain more clearly his views upon a subject he had so well considered, and witness the proposed trials of his shells. He had often wished for an opportunity of experimenting with the shells, to improve or adapt them to the various requirements of the service.

It appears to us that steam vessels of war should possess the following qualifications: That the motive power (so far as steam is concerned) should be out of reach of an enemy's shot. That the vessel herself should be proof against damage from either shots or shells. That she should have the capability, when required, of great speed, combined with the power of choosing under all circumstances her position with certainty and facility.

These qualities, we believe, may be combined in one vessel: *First.* By having the engine and boiler placed below the waterline, and using as a propeller Stevens circular scull, whose action is entirely below the surface of the water. *Secondly.* By constructing the vessel above the waterline of such materials as should be proof against shot and shell, and placed at such an angle as should best resist or turn the one or the other. *Thirdly.* By working the engine expansively in ordinary times, with boilers capable of resisting a high pressure, and of generating by the use of a more concentrated and inflammable fuel, a very large quantity of steam, giving greater power and speed when required.

In the construction of the vessel we propose to substitute iron for wood—iron for shipbuilding being of less weight than wood of equal strength, and capable of opposing an equal resistance.

The thickness necessary to resist balls of the largest

size would require to be determined by experiment. This could be easily and quickly done; but we suppose a thickness of one-half or two-thirds the diameter of a ball, set at an angle of 45 deg., would be sufficient to resist or glance it off. If so, it would require only 4½ or 6 inches to resist a 9-inch shot.

Since the above was written the following experiments were made: *First.* With a turned cast-iron ball weighing two-thirds of an ounce, being 11/16 of an inch diameter, fired with one-third of its weight of powder. At a distance of twenty-four feet from the target it passed through a thickness of 7¼ inches of seasoned white oak. *Second.* Same as above, except the ball passed through 7¼-inch target and penetrated one-inch oak piece behind it. *Third.* Under same circumstances, fired at wrought-iron target 5/16 inch thick, the ball passed through it. *Fourth.* Wrought-iron target ⅜ inch thick, set at an angle of 45 deg.; the ball just broke through it. *Fifth.* Target ⅜-inch iron, placed at right angles to line of flight, the ball passed through and penetrated one inch into a piece of white oak. *Sixth.* Target ½ inch thick, circumstances same as No. 5. The ball penetrated 13/32 of an inch, slightly fracturing the target on the back. *Seventh. Cast-iron* target 9/16 inch thick. The ball made a hole of its own diameter, scaling off the back. *Eighth.* Target of *cast iron*, ⅞ inch thick. The effect on the target the same as No. 7. The ball rebounded, and was compressed and flattened. *Ninth. Cast-iron gun* 26½ inches long. Cast-iron ball turned to fit the bore, 1¾ inches diameter, weighing eleven ounces; charge one-third the weight of the ball; distance of target, twenty-four feet. The ball penetrated 10 inches into white oak. *Tenth.* The target at 7½ feet distance; the ball penetrated 14 inches. *Eleventh.* Target wrought iron, 15/16 inch thick, 7½ feet distance. The ball was found firmly imbedded in the target, apparently half its diameter. The target was slightly fractured on its back, immediately opposite the ball. *Twelfth.* Distance, ball, load, etc., same as No. 1; wrought-iron target ¼ inch thick placed at an angle of 30 deg. with the flight of the ball. The ball broke and ricochetted, making an impression of ¼ inch in depth and 1¼ inches long without fracturing the iron. *Thirteenth.* At an angle of 37½ deg. the ball was broken and a hole made through the target nearly at right angles to the surface of the iron. *Fourteenth.* Target placed at an angle of 33¾ deg. Effect nearly the same as No. 13, except that the hole through the target was ½ inch instead of 11/16 inch. *Fifteenth.* Target placed at an angle of 30 deg. Effect same as No. 12, except that the iron was slightly fractured on the back.

From the above experiments it would appear that it takes wood sixteen times the thickness of iron to offer the same resistance to a ball, fired with a full charge. Four inches of wrought iron therefore would be equal to 5 feet 4 inches of oak, which we suppose sufficient to stop the horizontal ball at point-blank distance. Whether this ratio would hold good when balls of the largest size were used, experiments easily made will prove. We believe it will.

If a submerged application can be used at sea, with the same advantage and with no greater loss of power than takes place in our rivers, in the comparative power of the *water wheel* and *circular scull*, there can be but little question of the propriety of adopting the submerged propeller.

A steamship with her motive power completely protected would have an advantage equal to that an ordinary ship would have over her adversary by going into action with sails, rigging, and masts protected from the enemy's shot. An experiment on such a scale as to test fairly the value of a submerged propeller at sea would, we think, fully repay the cost to the government. We have but little question of its success.

We would propose to rig the vessel in the ordinary way, and to depend upon her sails for cruising, with the exception of a small power to overcome the friction of the propellers, if it should prove difficult or not advisable to unship them.

We would arm her with a few guns of the largest caliber, made of the same material as the one lately constructed by Capt. Stockton, viz., wrought iron, that the experience of the present forge is competent to execute, or having greater strength in proportion to their weight and capabilities of resisting larger charges, and throwing shot to a greater distance than any now in use. We would load them at the breech, which would enable us to rifle the gun, and by casting a thin covering of lead or pewter around the shot or shell, and making it a perfect sphere or cylinder, it would enable us to make the diameter of the ball the full caliber of the gun, doing away entirely with windage, and of course increasing the range and accuracy of flight of either shot or shell. This covering could be cheaply and quickly put on, and would protect the shot from any alteration of form by rust, and enable us to use and keep in order a more perfect gun. The remainder of the armament would be short guns of large caliber, to throw a great weight of shot or shell at short distances.

For harbor defense, we propose to construct a vessel whose principal means of offense should consist in her great strength and capability of resisting, without injury, a shock that would sink her opponent. That no two steam vessels of war at the present day could come together at a speed of say six or seven miles an hour, without sinking one or both, is in our opinion certain. What, then, must be the effect of coming in contact with a vessel, safe from shock herself, at double that speed? Instant and immediate destruction.

The only question seems to be, Could a vessel be constructed with the requisite strength and speed? If this can be done, and we are sanguine that it can, armed with shells, and completely proof against shot of any size, one would protect a harbor, and be more than a match for a fleet of steamers or ships of war of the usual construction.

Your obt. servants,

J. C. and E. A. STEVENS.

Note.—This committee made an elaborate report giving a history of the experiments, and unanimously agreed that the iron plates tested by them successfully withstood the numerous shots fired from the heaviest guns then in service, viz., 64-pounders.

It would appear to the lay mind that the report of experiments made by a board appointed by a department or departments of the government at Washington would be on file in the department as a part of the public business. More than one search has been made for the result of these trials at Sandy Hook, and thus far no trace of this official report has been found among the official documents. The report is no doubt among the official papers, but out of its proper place. It would seem more than probable, taking the surrounding conditions of that period into consideration, that it was intended that this report should never become public property, to be of service, at the time, to opposing interests or to foreign governments. The most of the details thus far to be obtained of these trials are to be found in Robert L. Stevens's letter of January 25, 1842, and that of John C. Stevens of January, 1846.

Robert L. Stevens was the better known of the Stevens family as the marine engineer, while his brother, Edwin A. Stevens, had made a specialty of railroad engineering and locomotive practice.

(To be continued.)

GERMICIDAL EFFECT OF SUNLIGHT.

SENSITIVENESS OF BACTERIA TO LIGHT.

BY DR. RICHARD WIESNER.

IN a recently completed research I have been able to correct a number of doubtful and erroneous theories of the effect of sunlight upon bacteria and to discover many hitherto unknown facts. One of the most important of these is the fundamental difference between two great classes of bacteria in regard to their sensitiveness to light. All those bacteria which normally live, either as disease germs or as harmless parasites, inside the bodies of men and animals are greatly affected and even killed by exposure to sunlight. On the other hand, the bacteria that live in the open air are but slightly or not at all affected by such exposure. For example, the *Staphylococcus pyogenes aureus*, one of the commonest producers of purulent inflammation, is so completely destroyed by light of sufficient intensity that not a single germ of a colony numbering 300,000 is found to survive two hours' exposure. During the same exposure to light of equal intensity the *Sarcina lutea*, a harmless and very widely distributed free-living bacterium, increases more than twofold.

There are, however, some exceptions to the rule that free-living bacteria are unaffected and parasitic bacteria are killed by light. Not only do different species of the latter group exhibit different degrees of resistance of light, but similar differences exist among individuals of the same species, according to their ages. The youngest germs are most rapidly destroyed by the sun's rays. A five-hour-old germ can endure six times, a seven-hour-old germ ten times, an exposure that would kill a two-hour-old germ of the same species. The disinfecting action of the sun's rays is independent of the number of germs exposed to them. In cultures of different density of population the relative mortality is the same, and equal exposures are required for total extinction.

High atmospheric humidity diminishes the germicidal effect, because it weakens the light by absorption, and dried germs succumb sooner than moist germs. The rapidity of destruction varies with the medium in which the bacteria have been cultivated, and increases with the thinness of the layer and the degree of desiccation. The temperature of the air also affects the result, as cold greatly retards and heat accelerates the germicidal action of sunlight. Bacteria are most quickly destroyed when the conditions are such that they can absorb little or no nourishment during insolation, as the heating action of the sun's rays increases their vital activity and need of food, as well as their excretion of waste products which are poisonous to them.

The germicidal power of the luminous rays and the far greater power of the ultra-violet rays have long been known. My investigations have proved that the ultra-red rays have similar properties. I found that bacteria were killed by exposure to sunlight under ray filters of smoked glass and a solution of iodine in bisulphide of carbon, which allow only the ultra-red rays to pass. The efficiency of the ultra-red rays was further proved by covering one culture with glass and a similar culture with a plate of rock salt. Glass and salt are equally transparent to the luminous rays, but glass stops the greater part, while salt absorbs very little of the ultra-red radiation. The bacteria exposed under rock salt were destroyed much more rapidly and completely than those which were covered by glass. For example, the number of living germs fell from 284,000 to 7,000 under rock salt, and from 284,000 to 213,000 under glass during equal exposures. The difference is due to the great germicidal effect of the ultra-red rays. By experiments with ultra-red rays artificially produced in a dark room it was proved that this action is a specific property of ultra-red rays, and not merely a consequence of their heating effect.

Direct sunlight and diffused daylight have precisely the same qualitative effect, though quantitatively the former is far superior to the latter. Still, the action of diffused daylight is sufficiently powerful to cause the total effect produced when cultures are exposed in sunshine to exceed, very appreciably, the effect of the direct rays of the sun alone, when the diffused light is cut off by screens. It was proved by experiment that the total effect is almost exactly equal to the sum of the separate effects of the direct rays and the diffused daylight.

Another series of experiments showed that the germicidal action commences at the first instant of the exposure and ceases promptly at its termination. In intermittent exposure with equal and very short intervals of light and darkness (a few hundredths of a second) the effect is strictly proportional to the aggregate actual exposure—that is to say, two hours of such intermittence are equivalent to one hour of continuous exposure to light of the same character. I also made the very remarkable and important discovery that the virulence or disease-producing power of bacteria does not cease at the instant of their death, but continues undiminished until their dead bodies have been entirely destroyed.

For the purpose of determining the hygienic value of disinfection by sunlight, I made a series of photometric experiments, which proved that the germicidal effect is directly proportional to the intensity of the light. Hence the disinfecting power of sunlight must vary greatly with the season, the weather, and the hour of the day. At and near noon on cloudless summer days the sun's rays are sufficiently powerful to destroy most bacteria, and disease germs in particular, in from two to two and one-half hours—a period which represents only a small fraction of the duration of sunlight in summer, spring, and early autumn. Other factors, including high air temperature and more perfect desiccation of germs, aid in making sunlight a powerful natural agent of disinfection at such hours and seasons. The great decrease in the so-called "cold" diseases (pneumonia, bronchitis, etc.) in summer suggests that their virulence is diminished by the disinfection of the air by the sun's rays.

Disinfection of the interior of houses by sunlight is a very different matter. Photometric tests showed that the illumination just inside a window was only 1/7, and that the illumination 13 feet behind the window was only 1/69; of the illumination outside the window; as our rooms are further darkened by furniture and curtains, thorough disinfection by means of sunlight is apparently hopeless.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from Umschau.

SOME ANCIENT METHODS OF LIFTING STONES AND TIMBER.*

THE MECHANICAL CONTRIVANCES OF OLD.

BY CLEMENT E. STRETTON, C.E.

At various times we hear the question asked: "How did the ancient stone masons raise the enormous blocks of stone which they used in their temples and pyramids to the heights and positions in which they are now found?"

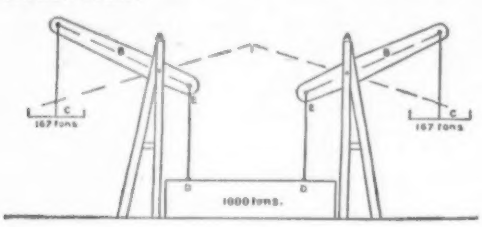


FIG. I.

It is fortunate that the work of the Egypt Exploration Fund, which had for its object the excavations in order to elucidate the history and arts of ancient Egypt, and the Egyptian Hall Exhibition of July, 1888, placed before us means of investigating the ancient methods.

The records of the Indian and Chinese building guilds prove that "square-masons" and "arch-masons" have been employed for about 5,000 years, and it is interesting to observe that the "square" builder used square stones only, and that round columns, arches, or curved work was carried out by a special class of men who did arch work only.

Arches are found in Chinese bridges of great antiquity, and investigations prove that in one of the

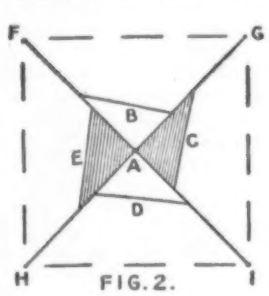


FIG. 2.

Egyptian pyramids, the "Hawara," there is an arched top to the sarcophagus chamber.

As stated in works upon the subject: "Those of Egypt far antedate the periods of Greece or Rome. Arched vaults are also found among the ruins of Nineveh."

One authority (Wilkinson) traced the arch to the time of Amenhotep I., who reigned 1540 B. C.; and he also considered that the arched chambers of the Pyramids at Memphis carried the antiquity of the arch back to 2600 B. C.

The stone arch at Saqqara is of the period 600 B. C., and the stone arches of the tombs of Beni Hassan are coeval with Usertensen II. and the Viceroy Joseph.

Spon's "Dictionary of Engineering" describes an arch as "a form of structure in which the vertical forces, due to the weight of the material of which it is composed, are transmitted to the supports."

Haydn's "Dictionary of Dates," page 51, states:

"Arches, Court of, the most ancient consistory court; it derives its name from the church of St. Mary-le-Bow, London, where it was formerly held, and whose top is raised on stone pillars built archwise."

The "Treasury of Science," Maunder, states that the Court of Arches is the Supreme Court belonging to the Archbishop of Canterbury, and that the name originated from the court having been held in Bow Church, London, which was built on arches.

Bow is also the name of an instrument which consisted of a large arch of 90 degrees graduated.

From an ancient building guild the writer finds that Bow Church was built by arch stone masons, known as "Companions of the Arch Guild." It was designed by the master of their guild, and was considered a masterpiece of arch-tect.

A bow carpenter was a trade to itself in ancient building history, his work being to make the bow or center of wood upon which the arch mason constructed his stone arch.

In the case of very large blocks of stone, such, for instance, as the corner footing stone of a temple, the ancients undermined the huge block of stone in the quarry, so that rollers could be placed under it. Therefore, when the stone was completely cut out it rested upon rollers, and did not have to be lifted. On arrival at the site of the building, the stone was rolled onto a stage of timber constructed in the space for the foundation. The stone then was "eased up" sufficiently to enable the stage to be pulled away to the side, and the block was lowered into its position. So it will be seen that in the case of "footing stones" there was very little lifting.

For lifting, the ancients used the method here illustrated, Fig. 1, and the system is clearly cut by them on the stones of some of their buildings.

Stanchions (*A*) were erected about 100 feet in height. Balance beams, or levers of the first order (*B*), were then placed in position. If the levers are three to one in favor of the power, it follows that a dead weight of 167 tons at *C* will lift 500 tons at *D*, and the 1,000-ton stone must slowly rise.

When the stone had been raised a few feet, blocks of wood were placed under it; the levers were returned to the former position, the chains from *E* to *D* shortened, and the process was repeated.

Slowly, but surely, the ancient stone masons lifted enormous weights to any height by this system. We are told that the Great Pyramid took twenty years to build, and that no fewer than 100,000 men were employed for that period.

There was unlimited labor, and an ample number of men to carry up the necessary weights to the platform (*C*).

After the stonework had been raised above 100 feet, another form of lever was used, the fulcrum of which rested upon the stonework already erected, it being a combination of levers of both the first and second orders.

The illustrations which the ancients have cut upon stones in Egypt, India, and the Holy Land show more clearly than words how they carried out their wor', and the building guilds of to-day confirm the information thus recorded.

Fig. 1 shows at a glance that the ancients had a perfect knowledge of levers and balance weights, and that they had great knowledge of "wood craft," or they could never have designed the stanchions and balance beams capable of lifting 1,000 tons weight.

Builders and surveyors often ask: "How did the ancients set out their work on the ground?"

Their system of "setting out" was known as "the five-point method"; it was used for *all* the pyramids, and is cut upon the stone of some of them.

Fig. 2 illustrates the ground plan of a pyramid, the center (*A*) being decided upon by the king, who, himself, with the usual ceremony of the period, made a center mark on a stone with a center punch, at the same time remarking: "There is the center of the intended structure, work ye to it."

The master builder from this center laid out four right-angled triangles by the well-known 3, 4, 5 method *B*, *C*, *D*, *E*. Then from the center (*A*) a line was measured to the four corner points, being half the intended diagonal length. The size of the pyramid was decided upon by the king, who gave the distance measured from *A* to *I*, *H*, *G* and *F*. The length of the sides followed as a matter of course, but it was not considered in the laying out, which was simply based on the center and four corner points.

Ancient tradition informs us that "6 times 60 = 360 cubits was the length of the great pyramid from the center to the corners," and modern experts estimate the length from the center as 546 feet.

As the building progressed a plumb line was suspended exactly over the center which the king had struck, and from that line the four corners were kept true until the work was nearly completed. It was a well-known maxim that "if they kept true to the center the corners could not err."

It will, of course, be understood that the original

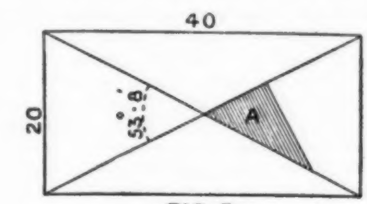


FIG. 3.

center stone remained in position, and a means was left to get to it in order to ascertain that the work was being carried out "dead upright."

Finally, the plumb line was removed and the apex stone placed in position, the ways to the center were built up solid and the work completed.

The four corner footing stones and the apex stone then formed the five points and gave the name to the ancient method.

For oblong buildings the ancient masons used the same five-point system, but the angles between the diagonal lines at the center were different. The angle at the center of a square building is, of course, 90 deg. A building having its length equal to twice its width has an angle between the diagonals of 53 deg. 8 min., as shown in Fig. 3, the 53 deg. 8 min. angle of the "3, 4, 5" set-square being used (*A*.)

In the case of King Solomon's celebrated temple, which was 60 cubits by 20, or 3 to 1, the 36 deg. 52

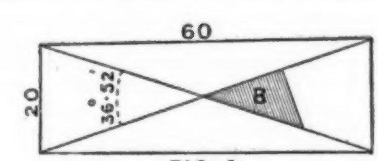


FIG. 4.

min. angle of the set-square was employed as illustrated (*B*) Fig. 4.

It will thus be seen that the three angles of the same "master's set-square" were used for the laying out of the three forms of building, and it is easy to understand the reason why the building trade secret of laying out on the center was then preserved by the various "guilds" and "castes."

The skill of the ancient stone masons was very great, but it seems a terrible waste of time, men, and material to employ 100,000 men for twenty years to build one pyramid to form the tomb of a king of Egypt; how much more use would it have been if they had then constructed the Assouan dam, which was recently designed by the late Sir Benjamin Baker, and which has regulated the flow of the River Nile, secured the water for irrigation purposes, thus giving benefits to Egypt which are incalculable to the inhabitants of that country at the present day.

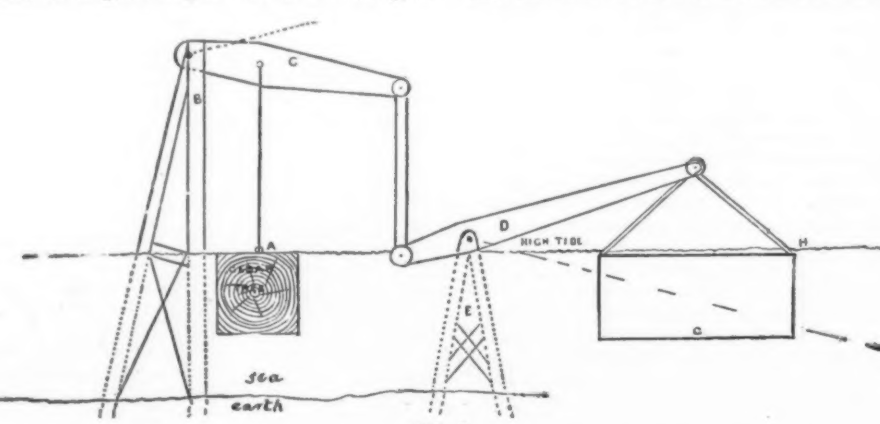


FIG. 5.

The double lift shows that weight had to be carried up to provide the necessary power, but in Fig. 5 it will be noticed that the dead weight of sea water provides the power.

This form of lift was used at Joppa to raise the cedar and fir trees from the floats mentioned (I.

* A paper read before the Leicester meeting of the Railway Club.

Kings, v. 9), and was a very simple and mechanical appliance.

At the Egyptian Hall Exposition of July, 1888, a model was shown of which the annexed diagram is a copy, and a similar model was at the Chicago Exhibition of 1893.

A is the tree to be lifted. *B*, the stanchion erected in the sea a short distance from the shore. *C*, a lever of the second order. *E*, another stanchion, which carries *D*, a lever of the first order. *F*, a connecting rod between the two levers. *G*, a large tank capable of holding a vast weight of water, and open at the top.

All being ready, the tide rose to *H*, and the sea filled the tank *G*.

When the tide went down, the tank of water went down, and the cedar tree went up.

At the conclusion of the first lift, a plug, or door, was opened in the tank, the water was released, and the tank placed again in the position shown. The chain from *C* to *A* was shortened, and the process repeated.

It was stated at the Chicago Exhibition of 1893 that the apparatus was designed and constructed by Adoniram (I. Kings, v. 14), and that some remains of the timber stanchions were to be found in the sea at Joppa at that date; also that three separate lifts had to be made, requiring three high tides, in order to get the tree up from the sea to the shore.

On the other hand, the Egyptian Hall Exhibition claimed that the arrangement was used on the Nile at an earlier date, and the building guilds in India claim that it was used by them 5,000 years ago.

Whatever the date of the invention, a working model which the writer has works perfectly, and illustrates the skill used by the ancient masons and workers.

ROBERT FULTON AND THE CENTENARY OF STEAM NAVIGATION.

FROM AN ENGLISH POINT OF VIEW.

It is difficult in this year of grace to realize that it is only one hundred years since navigation by steam actually reached the position of a recognized commercial means of transport, nevertheless such is the case. This outcome of the successes and failures of more than one generation of inventors was brought about in the New World five years before the same result was attained in the Old World. Perhaps their extensive inland waterways and long distances offering greater scope than anything in the Old World for improved means of transit, explain the greater activity that was there displayed. A brief account of the events that led up to what may be called a landmark in material development, and of the circumstances in connection with it, is not therefore without interest, especially as at this distance of time it is easier than it was while the events were taking place to decide among conflicting claims, and assign the proper proportion of credit to the chief actors.

For the sake of brevity we must perforce exclude mention of all ideas, proposals, or experiments which did not lead to a definite result. It should be borne in mind that paddle wheels and float boards worked by muscular power had been known from very early times to be capable of propelling a boat, and that at the period of first recorded success the atmospheric engine occupying much space and of great weight in proportion to its horse-power was the recognized prime mover, also that to obtain rotative motion Watt's patent engine had only just become available.

John Fitch, after about a year's experimental work, obtained from the State of New Jersey an exclusive right for fourteen years to make and use all kinds of steamboats. On the strength of this, Fitch formed a small company, and in 1786 succeeded in moving a skiff on the Delaware River by means of a small engine actuating paddles on either side alternately in close simulation of the muscular motions required in paddling a canoe. In the following year, having obtained a similar privilege from the State of Delaware, he fitted to a boat 45 feet long and 12 feet beam a horizontal double-acting low-pressure engine with cylinder 12 inches diameter by 3 feet stroke geared up to an axis, which moved twelve vertical paddles in four sets, three on either side acting alternately. Remembering the state of the mechanical arts in New England at that time and the clumsy method of propulsion, it was a great achievement to obtain, as he did, a speed of three miles per hour. This was on August 22, 1787—almost twenty years to a day before Fulton's success.

James Rumsey, who had commenced his experiments with models a year earlier than Fitch, adopted hydraulic propulsion—an old idea, but now for the first time reduced to practice—and succeeded in 1787 and again in 1788 in propelling a boat on the Potomac at the rate of four miles per hour. Proceeding to this country, he obtained a patent in 1788, succeeded in getting financial assistance, and his system was tried on the Thames in 1793. His death occurred on the eve of the experiments, which, although successful, were in consequence carried no further.

We must allude briefly to the well-known experiments of Patrick Miller with paddle wheels applied to double-hulled boats. For propelling one of these William Symington in 1788 supplied him with a form of atmospheric engine having a rotative motion obtained by pitch chains and ratchets, as patented by him in 1787. The engine had two cylinders, 4 inches in diameter by 9 inches stroke, and a speed of five miles per hour was realized on some water in Miller's private domains at Dalswinton, Dumfriesshire. This led to a trial on a larger scale in the following year on the Forth and Clyde Canal with an engine of 18-inch cylinder made at Carron, applied to a double boat that had been used in previous experiments at Leith, with, as might have been expected, a better result, i.e., seven miles per hour. Miller evidently only thought of this success as an auxiliary to inland navigation; indeed, the engine was of such a construction that it could hardly have been applied commercially. He ordered the engine to be taken to Carron, and the vessel to be laid up, disappointed, apparently, at the reception by the government of his day of his other public-spirited efforts directed toward improvements in the arts.

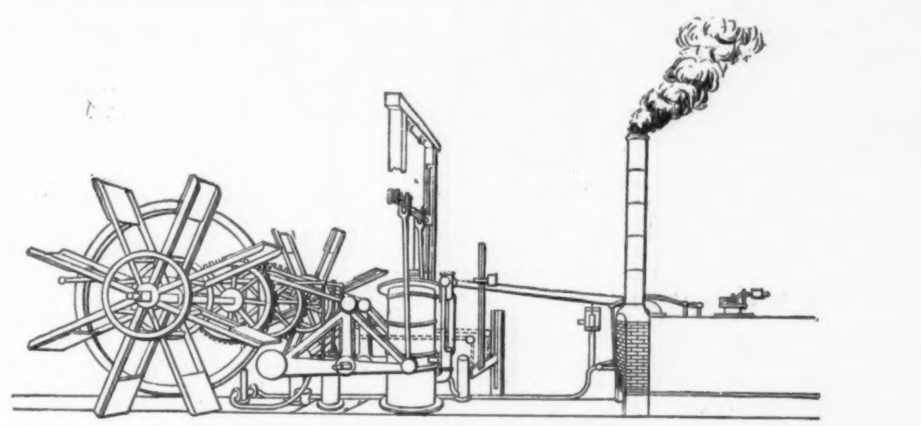
Meanwhile, in 1788 John Fitch and his partners had built their third boat; in this the paddles were placed at the stern, and a speed of over six miles per hour was realized on a voyage from Philadelphia to Burlington. A fourth boat on the same plan was decided upon, and after various alterations, was tested at Philadelphia in April, 1790, at the rate of eight miles per hour, in the presence of representatives of the State of Pennsylvania. She was placed upon the Delaware the same summer, and actually ran as a passenger and freight boat for three or four months between Philadelphia and Trenton, calling at intermediate places. In the autumn she was laid up, and not used afterward, as there had not been sufficient traffic to pay expenses; possibly the propelling arrangements occupied too much space. Fitch went over to France in 1791, but returned disappointed, and died in 1798.

Reverting now to Scotland, we find that in 1801 William Symington, at the request of Lord Dundas of Kerse, governor of the Forth and Clyde Canal, supplied an engine to the "Charlotte Dundas," built for experimental service on the canal as a tug in place of horse haulage. Symington made a great step in advance by employing the horizontal direct-acting condensing engine patented by him in 1801; the cylinder was 22 inches diameter by 4 feet stroke. This tug boat was tried in 1802 and was a complete success, but the canal proprietors decided that the erosion of the banks, which they expected would result from the wash of the paddles, would not be compensated for by any advantage likely to accrue from the use of tugs. She was therefore laid aside at Bainsford drawbridge, near Carron, and allowed to go to decay. However, Symington having submitted a model to the Duke of Bridgewater, received from him an order for eight similar boats for use on the Bridgewater Canal, but the death of that enlightened peer took place in 1803, before the work could be carried out.

In 1804, after three years' experimenting, Col. John Stevens, of Hoboken, N. J., constructed a boat which was propelled by submerged twin screws. The engine had a double-acting cylinder, non-condensing, 10 inches diameter by 24 inches stroke, working by side rods two crank shafts geared together by spur wheels so that no guides to the crosshead were necessary, an arrangement resembling that of Cartwright of 1797. Steam was distributed by two-way cocks moved by rack and sector, one at each end of the cylinder; the screws were four-bladed. The boiler was remarkable as an early example of the water-tube type; it had two sets of copper tubes, 1½ inches diameter by 18 inches long, plugged at one end and expanded at the other into a steam drum, the whole being in a casing with the grate at one end and the chimney at the other. The pressure was over 50 pounds per square inch, and the speed attained with this boat was four miles per hour.

We now approach the enterprise which was commenced a century ago, and was the immediate origin of the fleet of magnificent steamers that ply upon the Hudson and upon the Mississippi River, and was the proximate cause of the extension of steam navigation throughout the world.

It is not known when Robert Fulton first turned his attention to the subject of steam navigation, but he visited both this country and France, and it is known that he had opportunities of acquiring information at first hand as to what had been done already on both sides of the Atlantic. We find him in Paris in 1803, where he met Chancellor Robert R. Livingston, the accredited United States representative to the French government, who had been interested as early as 1798 in steamboat projects. Urged on and assisted financially by Livingston, Fulton made paddle-boat experiments on the Seine. The weight of the machinery broke the first boat in two; when placed in a second boat the speed was very slow, but the projectors were evidently satisfied, for Livingston obtained from the Legislature of New York an extension for twenty years of a privilege for navigating its waters by steam that had been granted to him in 1798, while Fulton ordered an engine suitable for his purpose from Boulton, Watt & Co. He made further trials on the Seine in 1804 without much better results. In that year he proceeded to England, and in person repeated his application at Soho for an engine. He also visited Symington, had a trip on the "Charlotte Dundas," and took full particulars of her. After an interval devoted to inconclusive experiments with submarine boats and torpedoes at the expense of the French and of the English government, he returned to his native country in 1806. In the spring of 1807 Charles Brown launched to Fulton's order from his shipyard at New York the "Clermont," named after the home of his friend and associate in the enterprise, Chancellor Livingston. This vessel was 133 feet long, 18 feet beam, 6 feet depth of hold, 2 feet 6 inches draft, and 160 tons customs measurement. The engine, which had been completed in 1805, and had been shipped to the United States before Fulton left England, was of the "bell-crank" type introduced by the makers not long before that date. It had a single cylinder, 24 inches diameter by 4 feet stroke, and was of 19 horse-power. The connecting parts and the paddle wheels were planned and executed by Fulton himself.


THE MACHINERY OF THE "CLERMONT."

The paddle wheels were 15 feet diameter, with floats 4 feet wide, dipping 2 feet into the water. The boiler was of the externally-fired tank type, 20 feet long, 7 feet deep, and 8 feet broad, and was set in masonry. The engine was open to view, as the stem and stern

were decked over for a short distance only. There were no outer bearings and guards to the wheels, which suffered damage in consequence. In this state on August 17, 1807, the "Clermont" ran her trial trip from New York to Clermont, proceeding thence the next day to Albany. The total voyage of 145 miles was made at the rate of nearly five miles per hour. Returning the day following to Clermont, Fulton proceeded to New York, having completed the return voyage at about the same speed. This was followed by a number of other trips, which were hardly successful financially. Before the season closed the paddle wheels were boxed in and outside guards fitted; during the winter of 1807-8 the "Clermont" was lengthened to 166 feet, flush-decked from stem to stern, and fitted with cabins and berths. Before the end of the season of 1808 she proved too small for the number of passengers who were anxious to travel by her. Her success aroused much jealousy, and she was often run into and damaged by the captains of sailing packets, who saw their business threatened. In 1813 her name had been changed to that of "North River."

Fulton, however, had only succeeded in beating Col. John Stevens by a few days. The latter, finding that the upkeep of high-pressure engines and boilers was difficult, had turned his attention to low-pressure engines and paddle wheels, and succeeded with a boat named the "Phœnix" in achieving a result similar to Fulton's. Deterred by the latter's monopoly of the Hudson, his son, Robert L. Stevens, in 1809 took the boat from New York to Philadelphia, and thus earned the distinction of having accomplished deep-sea steam navigation for the first time.

Fulton and Livingston quickly followed up their success with other boats of much greater displacement, some of them fitted with Boulton & Watt engines; they had six steamboats running before Henry Bell was spurred on to build the "Comet" on the Clyde, Scotland, in 1811. In spite of their monopoly on the Hudson, Fulton and Livingston drew but little profit from their enterprise, owing to the lawsuits in which they were involved by their opponents, who succeeded, in 1825, in annulling their exclusive privilege, which had been extended twenty years from 1807.

Robert Fulton died at New York on, February 24, 1815, at the age of fifty years, just as he had completed the first steam-propelled coast defense ship, having lived to see steam navigation in operation throughout North America and the continent of Europe.

Fulton stands out clearly, therefore, not as an original inventor, but as a discriminator who sees clearly and adopts just those parts of the inventions of others which are needed for success. Furthermore, he had sufficient financial backing to oppose the vested interests of the few and to outlast the ignorance of the many.—The Engineer.

THE DISINTEGRATION OF ATOMS.*

IS MATTER REALLY TRANSMUTABLE?

Man is prone to error. It was once believed that all inorganic things were inalterable. But the alchemists extracted bright metal from dull ore, expelled carbon dioxide from marble, and converted gray iron and blue vitriol (copper sulphate) into red copper and green vitriol (ferrous sulphate). After witnessing such changes in substances formerly regarded as immutable they naturally fell into the belief that all bodies were subject to change, and tried to convert lead into gold. This was another error, much derided in the nineteenth century, after it had been apparently established that the chemical elements, and they alone, are unchangeable and sempiternal. But this, again, was an error, as the new century has already shown. We have seen the element uranium decomposed into the elements lead and helium. We believe that even the elements are ephemeral, formed of one primordial substance into which they will ultimately be resolved again.

If this belief is another error it is at least one which will promote the advance of knowledge, as its forerunners have done. The evidence on which it is founded is, in brief, as follows:

In 1896 Becquerel discovered that certain minerals, especially pitchblende, which is composed chiefly of uranium oxide, emitted radiations that affected photographic plates wrapped in black paper, which rays of light cannot traverse. As these new Becquerel rays were not emitted by pure uranium oxide, freshly prepared, it was inferred that they were due to the presence of some other ingredient of the ore. Crookes separated pure non-radiating uranium oxide from a radio-active residue. Thus an astounding discovery was made. This residue, called uranium-X, lost all its radio-activity within six months, and in the same period the inactive uranium oxide regained all the radio-activity which it had lost through purification. Then an additional quantity of temporarily radio-active uranium-X could be extracted from the recuperated uranium. In other words, it was found that uranium continually produces fresh radio-active matter from its own substance.

A more sensitive and reliable detector of radio-activity than the photographic plate is the electroscope, which had already been employed in connection with the peculiar radiations produced by electrical discharges in rarefied gases. If two metal electrodes, sealed in a glass tube from which the air has been nearly exhausted, are connected with an induction coil provided with its battery and interrupter, the space between the electrodes becomes luminous and the negative electrode, or cathode, also emits non-luminous rays of peculiar properties. These cathode rays resemble the ultra-violet rays of the solar spectrum in that they move in straight lines, are reflected (at least by certain substances), cause fluorescence, and affect photographic plates, but they also possess electrical properties, and are deviated by electrostatic and magnetic forces. In addition, they possess so much mechanical or kinetic energy that they heat to whiteness bits of metal foil on which they impinge. Hence it is inferred that they are not vibrations, but streams of moving particles, carrying negative electrical charges. The velocities, charges, and masses have been calculated. Their maximum velocity is almost equal to that of light, and their average mass is 1/2,000 the mass of an atom of hydrogen. There is good reason for believing that these particles are atoms of electricity or electrons.

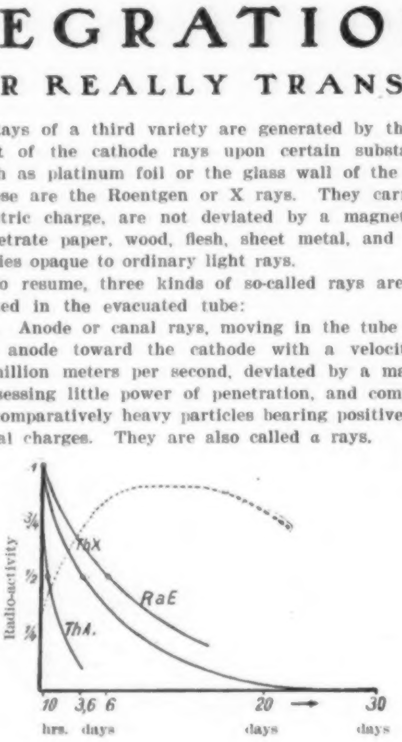
At the same time another stream of particles, forming the so-called anode or canal rays, moves in the opposite direction, from the anode to the cathode. These are positively charged particles of ordinary matter. They are much heavier than the cathode particles and move much less rapidly.

* Adapted from Umschau with additions by the Editor of Scientific American Supplement.

Rays of a third variety are generated by the impact of the cathode rays upon certain substances, such as platinum foil or the glass wall of the tube. These are the Roentgen or X rays. They carry no electric charge, are not deviated by a magnet and penetrate paper, wood, flesh, sheet metal, and other bodies opaque to ordinary light rays.

To resume, three kinds of so-called rays are generated in the evacuated tube:

1. Anode or canal rays, moving in the tube from the anode toward the cathode with a velocity of 3 million meters per second, deviated by a magnet, possessing little power of penetration, and composed of comparatively heavy particles bearing positive electrical charges. They are also called α rays.



2. Cathode rays, moving in the tube from the cathode toward the anode with velocities between 30 million and 250 million meters per second, deviated strongly by a magnet, possessing moderate power of penetration, and composed of exceedingly light particles bearing negative electrical charges. They are also called β rays.

3. Roentgen or X rays, emitted by objects struck by the cathode rays, moving with the velocity of light (300 million meters per second), not deviated by a magnet, possessing exceedingly great power of penetration, and consisting, not of particles of any sort, but of irregular pulses in the ether. They are also called γ rays.

The rays may be separated, as well as distinguished from each other by these differences, especially in penetration. A sheet of mica or a very thin sheet of aluminium completely stops the α rays, but transmits the β and γ rays, while a sheet of aluminium one-fifth inch thick or a sheet of lead one-twelfth inch thick stops both α and β rays, but allows the γ or Roentgen rays to pass.

All of these rays "ionize" the air, or make it a conductor of electricity, and therefore cause the divergent leaves of a charged gold-leaf electroscope to approach each other.

The rapidity with which the electroscope is discharged and the gold leaves brought together is proportional to the ionizing power. Calling the ionizing power of the γ rays 1, that of the β rays is 100, and that of the α rays 10,000. Hence the rays can be distinguished from each other, and their intensity, if only one sort is present, can be measured by their effect on the electroscope, which is so sensitive that it is discharged in one second by one ten-million-millionth (1/10,000,000,000,000) part of the radiation emitted by 1 gramme (15.4 grains) of radium.

The electroscope showed that the Becquerel rays contained two kinds of radiation, and that the photographic plate had led to slightly erroneous conclusions. The uranium from which the photographically active uranium-X had been removed still continued to emit α rays which affected the electroscope, but could not penetrate the black paper envelope of the photographic plate. The β rays, which penetrated the black paper and affected the plate, were emitted only by the uranium-X, but as the uranium compound from which this had been removed gradually regained its power to emit the penetrating β rays, the essential fact that uranium continually produces another substance of different radio-active properties remains unchanged.

It was soon discovered that radio-activity is not peculiar to uranium, but is possessed by thorium and tellurium, apparently also by lead, bismuth, and barium, and probably by all elements.

But by far the most strongly radio-active of all is the newly discovered element radium, extracted from pitchblende with marvelous patience and ingenuity by M. and Mme. Curie. Radium, which closely resembles barium in its chemical behavior, is always found associated with uranium in unvarying but very small proportion. One part of radium occurs in 3 million parts of pitchblende, of which, therefore, 406 pounds must be worked over to obtain a single grain (Troy) of radium. Of polonium, another radio-active element discovered by the Curies, only one grain (Troy) can be obtained from 400 *tons* of ore. In the course of experiments on radio-activity some twenty new elements, a list of which is given below, have been discovered.

It is a noteworthy fact that all the strongly radio-active elements have high atomic weights, and, as radio-activity is associated with the change of the element into something else, as we saw in the case of uranium, it appears that the heaviest and most complex atoms are foredoomed to destruction. The inference is suggested that elements of higher atomic weight than any now known have existed, but have disintegrated and vanished from the earth. It appears probable, indeed, that all the elements are disintegrating, though in most cases so slowly that we cannot detect the change, and that the earth will be in the end, as it was in the beginning, a mass of atoms of primordial matter, which can be reconverted into distinct elements only by the absorption of an immense amount of energy.

For radium and other radio-active elements emit, in addition to their peculiar radiations, enormous quantities of energy in the form of heat. In the course of a year a bit of radium generates a quantity of heat that would raise 8,000 times its weight of water from the freezing to the boiling point and is nearly equal to the heat produced by burning 1,000 times its weight of coal. Most of the new elements are found in quantities far too small to admit of chemical investigation. They are identified by their radio-active peculiarities, that is, the character and intensity of their radiations. The activity of thorium X, for example, falls to half its original value in 3.6 days and becomes inappreciable in a month. The decay of activity is graphically represented by the middle curve in the accompanying diagram, in which the radio-activity is measured vertically and the time horizontally. Each radio-active element has its characteristic curve. The diagram shows the curve of thorium A, thorium X, and radium E. The first loses half its activity in 10.6 hours, the second in 3.6 days, and the third in 6 days. For other elements this "disintegration period" is measured in fractions of a second, for still others in thousands of millions of years. The disintegration period of radium is 2,600 years, and an unknown substance that is found to have this period is thereby identified with radium. Curves of other forms are found. A mixture in which a strongly radio-active substance is being formed by the disintegration of an inactive substance, and is also disintegrating itself, gives a curve like the dotted line. At first the activity increases and the curve rises because the radio-active substance is being formed more rapidly than it is disintegrating. The horizontal part of the curve indicates that production and disintegration are equal, and hence the activity remains constant. Finally, owing to the exhaustion of the supply of the original substance, the active element is renewed less rapidly than

it disintegrates. Hence the activity diminishes and the curve falls. From a careful study of the curve of radio-activity the two substances may be identified, their disintegration periods and the rapidity of formation of the derivative substance determined, the presence of intermediate substances detected, etc. The names of the newly discovered radio-active elements (in addition to uranium and thorium), their disintegration periods and the kinds of rays which they emit during disintegration, are given in the accompanying table. Each element is produced by the disintegration of the element immediately above it in the series.

The "emanations" are gases which, though tending to remain occluded in the parent substance, can be expelled and collected. They confer apparent temporary radio-activity on inert bodies by adhering to them. The other elements in the table are solids. Most of them are produced in such exceedingly small quantities that they can be detected neither by chemical methods nor by sight, but only by their radioactive effects. In some of the transformations no rays are emitted.

its amount remains constant. The quantities of the two elements will then be proportional to their disintegration periods. Uranium, radium, and lead actually occur in pitchblende in the proportions given by this law.

Ramsay has recently observed the production of other known elements. Radium emanation, alone or mixed with hydrogen, generates helium. In contact with water, however, it generates neon, and in contact with solutions of copper or silver it generates argon also. (Argon, neon, and helium are three of the rare inert gases discovered in the atmosphere some years ago by Ramsay and Rayleigh.) Simultaneously with the gases other elements are produced which betray their presence by coloration of the liquid, slight precipitation, and particularly by their spectra. The presence of lithium has been established beyond a doubt, also that of sodium and calcium, but the latter widely distributed elements may possibly be derived from the glass of the vessel. These experiments open a new field of research of vast possibilities, for the disintegration of the copper atom, upon which the formation of lithium apparently depends, is not spontaneous, but is induced by the radio-activity of the emanation.

ELEMENT.	DISINTEGRATION PERIOD.*	RAYS.	ELEMENT.	DISINTEGRATION PERIOD.	RAYS.
Uranium	10,000,000,000 years	α	Actinium	?	?
Uranium X	22 days	β, γ	Radioactinium	19.5 days	α
.			Actinium X	10.2 days	α
.			Actinium Emanation	3 9 seconds	α
.			Actinium A	36 minutes	
Radium			Actinium B	2.14 minutes	α, β, γ
Radium	2,600 years	α			
Radium Emanation	3.8 days	α			
Radium A	3 minutes	α	Thorium	5,000,000,000 years.	
Radium B	26 minutes	β	Mesothorium	?	
Radium C	19 minutes	α, β, γ	Radiothorium	2 years	α
Radium D	About 40 years	none	Thorium X	3.6 days	α
Radium E_1	6 days	none	Thorium Emanation	54 seconds	α
Radium E_2	4.8 days	β	Thorium A	10.6 hours	β
Radium F (or Polonium)	143 days	α	Thorium B	55 minutes	
Radium G (probably lead)			Thorium C	A few seconds?	α, β, γ

* The "disintegration period" is the time in which the radio-activity, and therefore the quantity of substance not yet disintegrated, have been reduced to half their original values. The average life of an atom is obtained by multiplying the disintegration period by 1.443 approximately. The disintegration curve for any single element is an exponential curve, corresponding to the equation $r = c\,e^{-at}$, in which c denotes the initial quantity, r the quantity remaining undecomposed at time t, e the base of natural logarithms, and a the disintegration constant of the element. Hence it may be deduced that ar represents the absolute and a the proportional rate of disintegration at any time, and $\frac{1}{a}$ represents the average life of an atom. The "disintegration period" is expressed by

$$T = \frac{\log 2}{a \log e} = \frac{1}{a} \cdot \frac{0.301\ldots}{0.4343\ldots} = \frac{1}{a} \cdot \frac{1}{1.443}, \text{ approximately.}$$

Hence $\frac{1}{a}$, the average life, is approximately 1.443 T. The average life is represented graphically by the sub-tangent at any point of the curve, that is, by the length intercepted on the horizontal axis of time between the ordinate and the tangent drawn to the curve at any point. Assuming $T = 2{,}600$ and therefore $a = \frac{1}{1.443 \times 2{,}600}$, it can be calculated from the exponential equation that about 1/4000 of any given quantity of radium is disintegrated in one year and that one millionth remains after 50,000 years, as is stated in the text.

In all this there is no evidence of the production of either a new or an old element susceptible of examination or identification by chemical methods. But such evidence is not lacking. Ramsay and Soddy discovered that radium continually evolved helium, a gas of low atomic weight that had been discovered in the atmosphere a few years before. It was found impossible to free radium permanently from helium. Radium emanation (which is also a gas) was free from helium when freshly collected, but on standing it became contaminated with helium in proportion to the decay of its radio-activity. This astonishing result has been confirmed by many observers, so that the production of helium from radium (and also from actinium) may be regarded as an established fact. According to one view, the α particles expelled in disintegration are atoms of helium. In a year 1 gramme of radium evolves 219 cubic millimeters of helium—that is, several times its own volume. Yet the loss of weight is inappreciable, for in a year only about 1/4,000 of the original quantity of radium has disintegrated, and only a small part of this has escaped as helium, while the greater part (supposing that the emanation and other successive products have not been removed) remains mixed with the radium as an inactive final product, which, in all probability, is lead.

One millionth of the original quantity of radium would remain at the expiration of 50,000 years, but as the earth is very much older than that it might be supposed that all its radium must have vanished ages ago. As it has not vanished it must be continually generated by a parent element. From the constant proportion of radium to uranium in all uranium ores it is inferred that uranium is a progenitor, though the disintegration curve shows that it is not the immediate parent, of radium. The line of descent has been traced eight generations beyond radium to radium F. This is identical with polonium, already found as an ingredient of pitchblende. It has a disintegration period of 143 days and gives birth to a hypothetical inactive radium G, which is thought to be identical with lead.

When one unstable element thus produces another there comes a time when the second element disintegrates as rapidly as it is formed, after which epoch

Interesting cosmical speculations are suggested by the facts of radio-activity and disintegration of atoms. From the rate of disintegration of uranium and the observed proportions of helium and lead in uranium ores the age of those ores can be calculated, for the rate of disintegration, in marked contrast to ordinary chemical processes, appears to be independent of the temperature. It has been computed that a period of 16 million years would be required for the evolution of one cubic centimeter of helium from one gramme of uranium. Now, the mineral fergusonite contains 26 cubic centimeters of helium for each gramme of uranium, so that the age of this mineral must be at least 416 million years. In this calculation it is assumed that all the helium remained in the mineral. But a large proportion of it must have escaped, and consequently the calculated age is certainly too small. From the proportion of lead found in various uranium ores the average age of the latter has been computed to be 1,000 million years.

Another method of estimating the age of the solid crust of the earth is employed by geologists. The data on which the calculations are based are the depth and rate of erosion of river valleys, the thickness and rate of deposition of alluvial strata and salt deposits. These various ways lead to the same value for the age of the earth, 1,000 million years.

A third method, based on the loss of heat by radiation, gives a much lower result, 30 million years. From the velocity of propagation of earthquake shocks, as indicated by the seismograph, a thickness of about 43½ miles is deduced for the earth's crust. In this solid crust the temperature increases with the depth and, as heat always moves from warmer to cooler regions, there is a continual flow of heat from the interior of the earth to the surface. The surface, furthermore, receives heat from the sun and radiates heat into space. The heat thus lost by the surface must be nearly equal to the heat which it receives from all sources, for its mean annual temperature has remained nearly constant for thousands of years. The composition of saline deposits proves, as Van't Hoff has shown, that the mean temperature of the upper strata of the earth could not have been more than a few degrees higher many thousands of years ago than it is now. Now, Helmholtz and Kelvin have calculated, from the increase of temperature with depth, the thermal conductivity of the crust, and its probable temperature of fusion, that no more than 30 million years can have elapsed since the crust began to form. But, in addition to the fact that this result is so greatly at variance with the conclusions of the geologists, calculation shows that the heat thus received by conduction from the hot interior and the heat received directly from the sun, taken together, are not sufficient to supply the actual loss by radiation. Therefore the earth must contain some other source of heat.

The same argument applies, still more forcibly, to the sun. The sun is certainly older than the earth, but it constantly emits such enormous quantities of heat that it would have grown cold in a few hundred million years if it had not been supplied with heat from some source, external or internal. An external source has been sought in the impact of meteors under the influence of the sun's attraction, and Helmholtz endeavored to find an internal source in the gradual contraction of the sun's mass, but neither these nor ordinary chemical processes suffice to account for the quantity of heat emitted by the sun.

But the radio-active disintegration of atoms sets free a million times the amount of heat developed by ordinary chemical reactions. The presence of 3.6 grammes of radium in every cubic meter of the sun's volume would account for all the heat which the sun pours forth, although this flow of heat amounts to 850 million calories per hour for each square meter of the sun's surface.

For the earth very much smaller quantities of radium would supply the loss of heat and keep the surface temperature constant. The generation of one-fifth calorie annually in each cubic meter of the earth's mass would suffice, and this would result from the presence, in each cubic meter, of 1/4,000 milligramme of radium (about 3 millionths of a grain Troy in each cubic yard). The average proportion of radium in the superficial strata of the earth is thirty times as large as this. We have, consequently, more heat than we need. The discrepancy is obviated by the plausible assumption that radium exists only in the crust of the earth, not in the intensely hot interior. This assumption furnishes data for the computation of the probable thickness of the crust. The result is about 43½ miles, the same thickness that is obtained from seismic disturbances.

COAL IN PENNSYLVANIA IN 1906.

The total production of coal, anthracite and bituminous, in Pennsylvania, in 1906 was 200,575,617 short tons, having a spot value of $262,208,345.

The anthracite production amounted to 63,645,010 long tons (equivalent to 71,282,411 short tons), having a spot value of $131,917,694.

The production of bituminous was 129,293,206 short tons, having a spot value of $130,290,651.

In the combined production of anthracite and bituminous in 1906 the State exceeded any previous record.

Compared with the total production for 1905, which amounted to 196,073,487 short tons, the output last year exhibits an increase of 4,502,130 short tons, or 2.3 per cent, in quantity, and of $6,938,837, or 2.7 per cent, in value. All of the increase was in the production of bituminous coal, which showed a gain of 10,879,569 short tons over the 1905 production. Anthracite production, however, decreased 6,377,439 tons.

James E. Roderick, chief of the Department of Mines of Pennsylvania, reports that in 1906 there were 577 men killed and 1,212 injured in the anthracite mines, and 477 killed and 1,160 injured in the bituminous mines. In the anthracite regions 43 fatal accidents were due to explosions of dust and gas, 214 to falls of roof, 28 to explosions of powder, and 171 to other causes inside the mines. There were 101 fatal accidents outside the mines. In the bituminous region 10 deaths were due to explosions of dust and gas, 305 to falls of roof, 1 was due to an explosion of powder, and 139 resulted from other causes inside the mines. Twenty-two fatal accidents occurred outside the mines.

Until 1902 Pennsylvania had enjoyed uninterruptedly the distinction of producing more than one-half of the coal burned in the United States. In that year the shortage produced by the anthracite strike reduced the output of Pennsylvania to 46 per cent of the total production. Notwithstanding the increased production in 1903, the output of the State in that year was still slightly less than half of the total for the United States, and in 1904 Pennsylvania's percentage of the total was 49. The increase of nearly 25,000,000 tons in 1905 over the production in 1904 temporarily reinstated Pennsylvania in this respect, the State's production amounting to almost exactly 50 per cent of the total output of the United States. But the comparatively small net increase of 2.3 per cent in Pennsyl-

vania in 1906, when the total production increased 5.4 per cent, reduced the State's percentage to 48.4. It is doubtful whether Pennsylvania will in any future year contribute more than half of the country's total coal production.

Pennsylvania alone produces more coal than any other State or country in the world except Great Britain and Germany, and its output exceeds the combined production of Austria, France, and Belgium, which rank, respectively, as fourth, fifth, and sixth among the coal-producing countries of the world.

The rapid growth in the production of bituminous coal during recent years, compared with that of anthracite, has been marked, and forms one of the interesting features of the statistics of coal mining. From 1876 to 1880 the average production of bituminous coal in Pennsylvania was 1.41 times that of anthracite, while from 1901 to 1905 the bituminous production was 4.08 times that of the hard coal. It is not difficult to explain this comparatively great gain in bituminous production. For a number of years anthracite has been practically eliminated as a fuel for manufacturing purposes, and has been used almost entirely for domestic purposes in the Eastern States. And now, even for domestic purposes, the products of bituminous coal—coke and gas—are competing more and more with anthracite in the larger cities and towns. These conditions, and the constantly increasing cost of mining and preparing anthracite, furnish ample reason for the existing situation.

An advance chapter from "Mineral Resources of the United States, Calendar Year 1906," on the production of coal in 1906, by E. W. Parker, Chief Statistician of the United States Geological Survey, will be ready for distribution by the Survey in September.

ENGINEERING NOTES.

A new means of gaining access to the various holds of a steamer from the upper decks has been devised by Mr. Frederick Alcock of the Pacific Steam Navigation Company. Instead of reaching the various levels by means of the steep ladders generally adopted, a spiral staircase from the upper decks to the hold is carried in the ventilator casings. Access to the stairway is gained through a sliding door forming part of the wall to the shaft, while at the various holds a platform is provided. By this novel arrangement access to the holds is rendered possible whenever desired, a distinctly advantageous provision in emergencies, as when the cargo shifts while at sea, and so forth. The principle is now being applied to several vessels.

Experiments for the purpose of determining the best means of warning locomotive engineers of their approach to or passing of adverse signals, are being carried out by the German government authorities upon a section of track between Stettin and Berlin. In these experiments all practicable systems of extending warning in thick weather and at night are to be tested. So far it is stated a system of electrically-operated horns stationed beside the track in close proximity to the signal have proved the most satisfactory. The horns are from two to three in number, according to the importance of the signal in connection with which they work, placed at intervals of 100 yards, and carried on posts 9 feet high beside the track. This system so far having proved the most efficient method of warning the train engineers, it is being installed upon several miles of track.

The Panama Canal situation seems to be unnecessarily troubling a number of people having access to the columns of daily papers. The latter have been manifestly misled lately concerning the management of affairs under the new commission and the feeling of its leading subordinates. It has even been stated that the chairman of the commission was dissatisfied and wished to be relieved from his duties. While we have no knowledge of the opinions of Lieut.-Col. Goethals concerning his work, we are in a position to state positively that there is no such marked dissatisfaction with conditions among the technical employees of the commission as recent published reports would indicate. Wherever many thousand men are engaged on an undertaking which necessarily compels them to go without some of the comforts to which they have been accustomed elsewhere, a certain amount of grumbling and a few cases of positive discontent must be expected. Fortunately most discontented people went home before the present commissioners assumed office, and those who are now there are thoroughly alive to the importance of their work and to the credit that all will receive in due measure from participation in the undertaking. It is true that there was some apprehension in the engineering staff when military engineers were placed in control of the commission, but this disappeared as soon as the men had an opportunity of becoming acquainted with their new leaders. There will always be differences of opinion between those engaged on the work, which may lead in some cases to resignations, but there has never been a time when the force of canal builders felt more satisfied with their conditions than at present. Where work can be pushed it is going ahead energetically; where investigation is necessary in order to avoid mistakes, it is being made; and where the data for plans are complete, the designs are being pushed. There is no ground for any other statements.—Engineering Record.

TRADE NOTES AND FORMULÆ.

Preventing the Tarnishing of Furniture Mountings.—The tarnishing of metals, of furniture mountings especially, may be prevented by a protective coating. The mountings (according to the Deutsche Drechsler Zeitung) are first cleansed of grease by means of benzine or alcohol and then coated. A suitable medium is a single coat of dilute collodion; or, after a slight heating of the metal a coat of celluloid varnish.

Silver-Plating Processes and Recipes. (Abstracted from various European sources.)

Sig. Boelsterli, of Switzerland, has recently introduced a silvering compound composed of silver chloride dissolved in sodium hyposulphite. In 30 parts by weight of water, 0.8 part of silver nitrate is precipitated as chloride, by means of a 12 per cent muriatic acid. The precipitate is washed and then dissolved in a solution of 3.3 parts of sodium hyposulphite in 30 parts of water. To this solution is added, while stirring, 1.8 parts of 8 per cent spirit of sal-ammoniac and 8 parts of finely-powdered chalk. The mixture is applied to the articles, which are briskly rubbed until dry, and then rubbed with a woolen cloth.

An electro coating hint on the silvering of mirrors to prevent the scaling which sometimes occurs in the coppering of silver is as follows: To the galvanic bath employed for the electro deposit it is sufficient to add a quantity of the liquid used for the silvering, or of the salts of which the bath is composed, or substances possessed of similar properties. The quantities must be determined by trial.

By the Weldon process non-metallic articles are prepared for electro-silvering by being covered with a varnish more or less resisting, containing asphalt, and in which a metallic conducting powder has been incorporated. The articles are then dipped in a 10 per cent silver solution containing a few drops of alcohol.

A process for the electrolytic silvering or coppering of aluminium, recommended by Herr Nauhardt, is accomplished through a double cyanide solution in presence of an alkaline phosphate. For silvering, a solution is prepared, cold, of equal parts silver nitrate, potassium cyanide, and ammonium phosphate. For copper, copper nitrate is mixed with an equal quantity of potassium cyanide or ammonium phosphate. The precipitate is redissolved with a little muriatic or sulphuric acid, according to the salt employed.

The Fielder process for the cold silvering of metals consists in rubbing them with a rag soaked in the following mixture: Silver nitrate 15 parts, sodium chloride 300 to 350 parts, tartaric acid 80 to 100 parts, tripoli 350 to 400 parts.

A powder which will rapidly silver metallic articles is composed of silver nitrate 10 parts, sea salt 200 parts, crystalling flour 100 parts, distilled water 600 parts.

A tinning bath to which are added aluminium and magnesium salts will prepare metallic articles for gilding or silvering without the intervention of copper. Herr Nauhardt, who has introduced the method, recommends the following formula: Water 9 parts, sodium pyrosulphate 0.5 part, crystallized tin chloride 0.1 part, aluminium nitrate 0.05 part, and magnesium nitrate 0.05 part. This bath constitutes the electrolyte, the tin or aluminium sheet the anode, and the objects to be coated the cathode. After being thus tinned the articles are gilded or silvered.

A powder for silvering or resilvering jewelry or for the cleaning of silver is composed of silver nitrate 1 part, potassium cyanide 2 parts, chalk 5 parts. The object is cleaned, and then rubbed with a damp rag sprinkled with the powder. Afterward dry and polish with a clean linen cloth.

Compounds having a base of iron, such as ferro-nickel, etc., may be silver-plated by passing them through a bath of bichloride of mercury; rinsing them, then through a bath of bicarbonate of soda, and finally after a second rinsing, putting them in a bath of nitrate of silver. The mercury solution contains per liter, muriatic acid 35 cubic centimeters, sodium chloride 100 grammes, carbonate of soda 50 grammes, bichloride of mercury 6½ grammes. The silver solution is composed of nitric acid of the strength 36 deg. Baume, containing 30 grains of nitrate of silver per liter.

Silver may be oxidized by immersing it in a strong sulphur bath, composed of 100 grammes of potassium sulphide in a liter of water.

To make silver paint, pulverize silver leaf very fine and mix with honey. This is easy, and does not require special precautions; but the after-washing must be very thoroughly done. Several washings with warm water are necessary, and then the whole is to be mixed with white of egg and gum water.

ELECTRICAL NOTES.

R. I. Phelps contributes an article to the Mining and Scientific Press of San Francisco on the furnace plant erected at Héroult, Shasta County, Cal., to treat the magnetite ores found on the divide between the Pitt and McCloud rivers. The current available is three-phase 60-cycle alternating current, which has not hitherto been used in electric smelting. Three carbon electrodes are used, each 18 x 18 x 72 inches. The water-cooled stepdown transformers deliver to the electrodes 30,000 amperes at 50 volts 60 cycles from the 22,000-volt potential of the power transmission line. The first heat was started on July 4, but after a few hours' work trouble developed, and the heat had to be stopped. After several hitches smelting has now been resumed, and the first heat tapped.

A few years ago, Wehnelt showed that the difference of potential required to produce a discharge through a vacuum tube is very much diminished if the cathode be coated with an oxide of one of the metals of the alkaline earths, such as barium oxide or calcium oxide, provided that the cathode is then raised to a red heat by means of an independent current. Mr. A. A. Campbell Swinton has quite recently tested whether radium coated on the cathode produces the same effect. Moreover, as radium gives off electrons when cold, it was anticipated that it might be unnecessary to heat the cathode. Using a cold cathode with a thin coating of the bromide of radium, and with a continuous current up to 400 volts pressure, this was found not to be the case. A very marked action in facilitating the production of a luminous discharge was, however, observed when the radium-coated cathode was heated; in fact, a pressure of 80 volts was then sufficient. Further experiments showed that it is not sufficient that the radium be in the tube; it must be on the cathode for the effect to occur. Whether the radium salt is more or less efficient than barium or calcium oxide is rendered doubtful owing to the very small amount of radium employed. With the quantity actually used the efficiency was less, but this might not be the case if more radium were available.—Knowledge and Scientific News.

New Single-Phase Electric Road in California.—The recent suggestion for the operation of single-phase, alternating current, electric roads at 15 cycles in place of the common higher frequency probably will meet practical tests soon on an interurban road now under construction in California. The line is to extend from Visalia, Cal., through Exeter to Lemon Cove, 23 miles, and it is to be operated by the Visalia Electric Railroad. The power will be received from the Mount Whitney Power Company at Exeter, where a substation will be built to serve the electric road. Current will be received here at 60 cycles, 17,500 volts, and by means of two 450-kw. motor generator sets transformed to 11,000 volts at 15 cycles, and transmitted to the transformer substations. These substations will be located one near each end of the line, and one at Exeter; and the equipment in each will consist of two 300-kilowatt, 15-cycle transformers, which will lower the current to the trolley pressure of 3,300 volts. The trolley wire will be of No. 000 copper hung by catenary suspension from bracket arms on a single line of poles. The same poles will support the 11,000-volt transmission line. The car equipment will comprise four passenger cars and a 50-ton electric locomotive. The passenger cars will be equipped with four 75-horse-power motors each, with multiple unit control and air brakes. This car equipment and the substation apparatus will be furnished by the Westinghouse Electric and Manufacturing Company. The electric locomotive will carry four 125-horse-power motors, and the brake equipment will be the new automatic Westinghouse ET.—Railway and Engineering Review.

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